THUNDER BAY REGIONAL WATER QUALITY SURVEY

September 1972

Ministry of the Environment

Ontario

The Honourable William G. Newman, Minister

Everett Biggs, Deputy Minister

THUNDER BAY

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INTRODUCTION

This report presents the findings of water quality investigations conducted in August 1970 by the Ontario Ministry of the Environment (formerly OWRC) in the Lower Kaministikwia River and Thunder Bay Harbour areas. The study was undertaken to evaluate the degree and extent of water quality impairment indicated by earlier investigations (OWRC, 1965, 1969).

The report documents the major water uses and waste sources and discusses the existing and proposed municipal and industrial pollution control programs in the area.

Following a description of the water pollution problems the report presents a set of proposed water quality standards which would provide suitable quality for existing and potential uses of the water resources in the study area. Waste loading guidelines along with recommendations for the implementation of additional pollution control measures necessary for meeting the proposed standards are also presented in the report.

BACKGROUND

Former studies of the water quality and benthic community of the Thunder Bay area indicated a water pollution problem, the direct result of the industrialization and urbanization that has taken place in this area over the past two decades. The City of Thunder Bay is the largest Canadian city on Lake Superior. The population in 1970 was 106,540. (By comparison, the largest U.S. city on Lake Superior is Duluth, Minnesota with a population (1970) of 100,578. The combined populations of the twin cities of Duluth, Minnesota and Superior, Wisconsin, however, add up to over 130,000 making this centre the largest urban development on Lake Superior).

By the very virtue of its population and concentration of industry, the City of Thunder Bay is a potential contributor to the water quality degradation of Lake Superior. The open waters of this very large oligotrophic lake are thus far largely unaffected by man's influence primarily as a result of a lack of development around the lake. To ensure that the water quality of the lake be maintained at a high level, the Lake Superior Water Quality Technical Committee[1] developed recommendations which, if adopted and enforced at an international level, would preserve the existing high water quality of Lake Superior in the face of further population and industrial growth.

A biological survey was conducted by the OWRC during October 1965 to investigate the unpalatable nature of fish caught in the Kaministikwia River and the dwindling success of commercial fisheries which had been severely affected by fish tainting in Thunder Bay (OWRC 1965). This study found that the unbalanced nature, and in places, non-existence of bottom fauna communities were directly attributable to accumulations of wood fibre discharged from the paper mills, organic enrichment related to the input of untreated domestic wastes from the former cities of Fort William and Port Arthur, and starch wastes from Industrial Grain Products Ltd.[2]

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1 *Meeting on May 28, 1970 - representatives of FWQA, Michigan Water Resources Commission, Minnesota Pollution Control Agency, Wisconsin Department of Natural Resources and Canadian Federal and Provincial representatives as observers.*

2 *Formerly Ogilvie Flour Mills Limited.*

The wood fibre discharges originated from Abitibi Paper Company Ltd., Fort William Division; Abitibi Forest Products Ltd., Thunder Bay Division;[3] Abitibi Provincial Paper, a Division of Abitibi Forest Products Ltd.;[4] and The Great Lakes Paper Company Limited. In addition, the study indicated that water quality within Thunder Bay Harbour was moderately to heavily impaired.

In 1969, the Lakehead Area Regional water Supply and Pollution Control Study was released by the Ontario Water Resources Commission. This report provided plans for supplying water to the developing urban area of Thunder Bay and establishing pollution control facilities to maintain and improve water resources. The report concentrated its pollution control proposals on the municipal waste problem. It identified the inputs of sanitary combined and storm sewers to the rivers, harbour and bay and recommended construction of the necessary sewers and treatment facilities to ensure that all wastes from the urban area would receive a minimum of primary treatment. The report assumed that industries would be required to either provide their own treatment facilities at some time in the future, or that they would discharge to the municipal system.

In view of the water quality problems indicated by earlier studies and the increasing pressure exerted on the water resources by continuing industrial and municipal growth of the Thunder Bay area, the Ontario Ministry of the Environment undertook this detailed investigation. It is hoped that the information contained in this report will be useful for formulating optimal water quality management plans for the Thunder Bay area.

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3 *Formerly Abitibi Paper Company Limited, Thunder Bay Division.*

4 *Formerly Abitibi Provincial Paper Company Limited.*

CHAPTER I

SUMMARY OF FINDINGS

AND

RECOMMENDATIONS

1. SUMMARY OF FINDINGS AND RECOMMENDATIONS

1.1 SUMMARY OF FINDINGS

The surface waters in the Lower Kaministikwia River Basin, Thunder Bay Inner Harbour and the adjacent section of Thunder Bay Outer Harbour are being contaminated by local industrial and municipal wastewater discharges.

The industrial wastewater discharges were by far the largest source of pollution accounting for approximately 90 percent of the oxygen-consuming waste inputs (BOD_5) to the study area. Although the BOD_5 loadings from the municipal sources were much lower, these contribute significantly to the input of nutrients and bacterial contamination.

The Kaministikwia River downstream from the Westfort Turning Basin to the mouth of the river was the most seriously affected area in the study region, particularly in terms of nutrients, excessive loadings of oxygen-consuming wastes (BOD_5) suspended solids, accumulation of organic materials and metals including mercury in bottom deposits, bacterial contamination, aesthetic impairment and potentially toxic and tainting substances. For example, dissolved oxygen levels at the time of this study in the reach downstream from the Great Lakes Paper Company Limited to the confluence of the Kaministikwia, McKellar and Mission rivers were well below 5 mg/l which is considered to be the concentration necessary for the protection of warm water fisheries and other desirable forms of aquatic life. The bacterial levels found in the Lower Kaministikwia River and the three channels suggest that accepted criteria for swimming and bathing are exceeded. The appearance of the Kaministikwia River Basin which has been severely degraded by suspended materials, scum, coloured substances, and floating oily wastes, imposes further restrictions on the use of this basin for water-based recreational activities.

Impairment of Thunder Bay Inner Harbour was restricted to the extreme north and south sections which receive the major waste inputs in the harbour area. The main changes in water quality included decreases in dissolved oxygen levels, increases in nutrient materials and bacterial contamination in excess of accepted criteria for swimming and bathing. The dissolved oxygen levels, however, did not fall below 5.4 mg/l during the August study in this area.

Water quality degradation in the study portion of Thunder Bay Outer Harbour was restricted to the vicinities of the mill outfalls, the Lillian Street sewer and mouths of the Mission, McKellar and Kaministikwia rivers flowing into

the bay. The main changes in water quality included bacterial contamination and aesthetic impairment particularly in the vicinities of the outfalls. Contamination by fecal coliform and fecal streptococcal bacteria was in excess of the criteria for swimming and bathing in this portion of the study area except in the vicinity of the Bare Point pumping station. However, water quality in this area has been contaminated on several occasions under different weather and current conditions. Since the bacterial contamination was mainly due to fecal coliform and fecal streptococcal bacteria, this suggests that contamination in this area was caused by municipal wastes and sanitary wastes from industrial sources.

At the time of this study, water quality degradation due to the discharge of oxygen-consuming wastes and nutrient materials was not serious in Thunder Bay Inner Harbour and the adjacent area of Thunder Bay Outer Harbour. However, continuing discharges of these wastes on a long-term basis may lead to build-up of carbonaceous and nutrient materials which could cause water quality problems in the future. These discharges should, therefore, be controlled to the highest degree practicable to avoid the risk of water quality degradation similar to that which has already occurred in the Lower Great Lakes.

It is expected that significant improvement in water quality will occur particularly in the Kaministikwia River basin and the Thunder Bay Inner Harbour upon completion of the pollution abatement programs presently underway or proposed by the City of Thunder Bay and the major industries in the area. However, the dissolved oxygen levels in the Kaministikwia River during low flow periods still may not be sufficiently high to provide adequate protection of fish and other desirable forms of biota because of limitations in existing waste treatment methods. Nevertheless, with continuation of pollution control programs by the industries and the municipality and further advances in waste treatment technology, water quality in the area will ultimately be restored to an acceptable level.

1.2 RECOMMENDATIONS

In order to alleviate the existing pollution pressures in the Thunder Bay region, it is recommended that:

1. The City of Thunder Bay proceed as quickly as possible with its pollution control program to:

   i) provide primary treatment with nutrient removal and effluent disinfection for municipal wastewaters,

   ii) construct sanitary interceptor sewers to direct all sanitary wastes to municipal sewage treatment facilities.

2. The Great Lakes Paper Company Limited continue its waste treatment programs to:

   i) reduce and maintain the suspended solids solids level in its effluents below 50 mg/l,

   ii) reduce the organic wastewater loading (BOD_5) as far as possible (Figure 4.2 provides a guideline),

   iii) eliminate from all mill effluents substances which contribute to taste and odour problems in water and which are toxic or may contribute to the tainting of fish flesh,

   iv) segregate all sanitary wastes from process wastes and provide treatment or discharge them to the municipal sewer system.

3. Industrial Grain Products Limited complete as quickly as possible the waste treatment programs presently underway to eliminate the input of oxygen-consuming wastes to the Kaministikwia River.

4. Dow Chemical of Canada Company Ltd. continue to ensure that mercury losses from the chlor-alkali plant are kept to a minimum.

5. Abitibi Provincial Paper, a Division of Abitibi Forest Products Ltd.:

   i) reduce and maintain the level of suspended solids in the mill effluents below 50 mg/l,

ii) eliminate from all mill effluents substances which contribute to taste and odour problems in water and which are toxic or may contribute to the tainting of fish flesh,

iii) segregate sanitary wastes from mill process wastes and provide treatment or discharge to the municipal system.

6. Canada Malting Company Limited proceed with its proposed program to discharge all of its waste-waters to the municipal system once the construction of this system has been completed.

7. Abitibi Forest Products Ltd., Thunder Bay Division:

i) continue to maintain the suspended solids level below 50 mg/l in the mill effluents,

ii) eliminate from all mill effluents substances which contribute to taste and odour problems in water and which are toxic or may contribute to the tainting of fish flesh.

8. Abitibi Paper Company Ltd., Fort William Division:

i) continue to maintain the suspended solids level below 50 mg/l in the mill effluents,

ii) eliminate from all mill effluents substances which contribute to taste and odour problems in water and which are toxic or may contribute to the tainting of fish flesh,

iii) segregate all sanitary wastes from mill process wastes and provide treatment or discharge to the municipal system.

9. The Canadian National and the Canadian Pacific Railway companies eliminate the discharge of oil and other harmful materials that will contribute to the impairment of the waters in the Thunder Bay area.

10. Current studies be undertaken to define the mixing patterns in the Lower Kaministikwia River and in the Inner and Outer Harbour areas, particularly in the vicinity of the Bare Point pumping station as well as potential outfall locations for the proposed Thunder Bay sewage treatment plant.

CHAPTER 2

DESCRIPTION OF THUNDER BAY REGION

AND

RESOURCE USES

2. DESCRIPTION OF THE THUNDER BAY REGION AND RESOURCE USES

2.1 PHYSIOGRAPHY

Topography

The topography of the Lakehead Region may be classified into three broad types:

a) hummocky uplands, developed on crystalline early Precambrian rocks,

b) table lands, developed on late Precambrian rocks, and

c) lowlands underlain with pleistocene deposits.

The hummocky uplands, located to the north of Thunder Bay, although rocky and with a very uneven surface, are devoid of any deep land depressions. On the other hand, the table lands consist of areas of flat-lying sediments where erosion has produced broad valleys and left tabular uplands. The whole area has been subject to warping and faulting which produced sheer cliffs on one or more sides of each tabular upland. This topography is dominant in the southwest region of the study area.

The lowlands are located adjacent to the Kaministikwia River and sections of the Sibley Peninsula. They consist of thick deposits of gravel, sand and clay which cover bedrocks.

It is likely that the broad valley of the Kaministikwia River developed in pre-glacial times and was at least partially filled by the glacial debris left behind by the receding continental ice sheets. Under the enormous pressures of the ice, the Thunder Bay area soil cover was scoured from the bedrocks and set down again to establish the existing Kaministikwia River basin. The poorly drained areas consisting largely of peat and loosely packed muds that now are common throughout the region are a result of the glacial movements.

Drainage Channels

The Kaministikwia River rises in Dog Lake, situated about 20 miles northwest of Thunder Bay, and drains an area of approximately 3,020 square miles. The Shebandowan Lakes also feed the river via the Shebandowan River. Discharges from these

lakes are regulated by control dams to facilitate hydro-electric power generation.[1] From its source, the Kaministikwia River flows in a generally southerly direction until it changes course to an easterly direction about three miles downstream from Kakabeka Falls. The river gradient averages 18 feet per mile until the 128-foot vertical drop at the falls. Downstream from the falls the gradient is lower and the river follows a winding course. The lower five mile reach of the river from the Westfort Turning Basin to the mouth is wider and has been dredged by the Canada Department of Public Works to a nominal depth of 25 feet for commercial shipping.

Two miles upstream from its mouth the river divides into three channels: the Kaministikwia, McKellar and Mission rivers. The Mission River is also dredged to 25 feet for shipping, while the McKellar River is not dredged because shipping uses have been discontinued in this river.

Smaller streams flowing into the Thunder Bay Harbour are the Current, Neebing and McIntyre rivers as well as McVicar Creek. The upper reaches of these streams pass through steep, heavily-wooded terrain. Within the City of Thunder Bay, the watersheds are essentially flat and the rivers are at the elevation of Lake Superior with the result that some low lying areas of the City are subject to flooding during periods of high runoff. The exceptions are McVicars Creek and the Current River which both have a significant drop in elevation within the City boundary.

Maintenance dredging of the harbour is carried out each year to remove accumulations of sediment and organic materials originating from land runoff and domestic, storm and industrial waste discharges via direct and indirect discharges into the harbour.

In order to facilitate the discussion of the industrial and municipal waste inputs and their effects on water quality in subsequent sections of this report, the study area is divided arbitrarily into the following three zones:

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1 *The flow in the Kaministikwia River at Kaministikwia is also controlled by the operation of the Silver Falls Hydro-Electric Generating Station located about 10 miles upstream from the Community of Kaministikwia. This plant is operated mainly during the day time periods when low streamflows occur. Its effect is not considered to be significant at the Kakabeka Falls Generating Station due to the distance as well as the flow from intermediate storage reservoirs on the Shebandowan River.*

Zone 1 - The Kaministikwia River Basin including approximately 10 miles of river extending one mile upstream from the Westfort Turning Basin downstream to Thunder Bay and including the Mission and McKellar rivers.

Zone 2 - Thunder Bay Inner Harbour, including an area of about seven square miles, being bounded by the harbour breakwall on the east and extending southward from Bare Point to a point opposite the Kaministikwia River.

Zone 3 - Thunder Bay Outer Harbour - that portion of Thunder Bay adjacent to the Inner Harbour extending from Whiskey Jack Point on the south to the Bare Point pumping station on the north and ranging as far offshore as the Welcome Islands.

The respective boundaries of these three zones and location of the major waste sources are shown in Figure 2.1 and 2.2.

Climate and Hydrology

The climate in the Thunder Bay area is typical of Northern Ontario but is moderated somewhat by its proximity to Lake Superior. The monthly average temperatures vary from 7°F in January to 63°F in July. The frost-free period is usually 90 to 112 days in length with the annual precipitation averaging approximately 30 inches.

The small unregulated streams in the area are subject to rapid variations in flow as a result of varying precipitation. They have very low base flow rates during the long dry periods that typically occur from December to March and July to September. The mean April flow may be 35 times the low winter or summer flows.

Ontario Hydro regulates flow in the Kaministikwia River through its control and operation of the Silver Lake Dam and Generating Station, the Shebandowan Lake Dam and the Kakabeka Falls Dam and Generating Station. Water is stored and released in accordance with power generating requirements. In the past, the largest fluctuations in streamflow have been noted to occur for one to two day periods, usually on weekends, when industrial power requirements are lower. Variations in streamflow are not significantly reflected in the change in occupied volume of the lower Kaministikwia River (Westfort Turning Basin to Thunder Bay) due to the backwater effect of Thunder Bay on this section of the river.

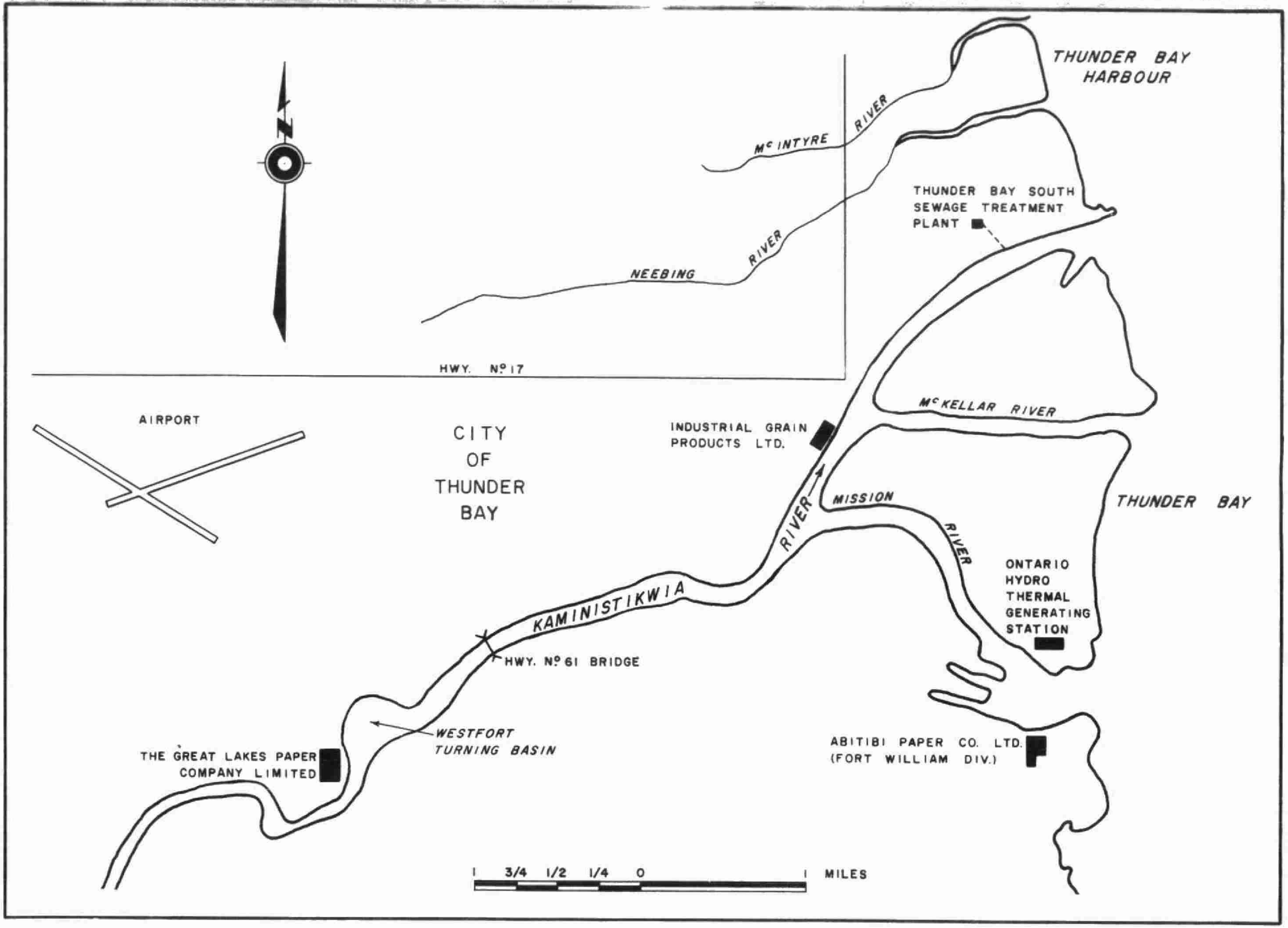

Fig. 2.1 Zone 1 - Lower Kaministikwia River

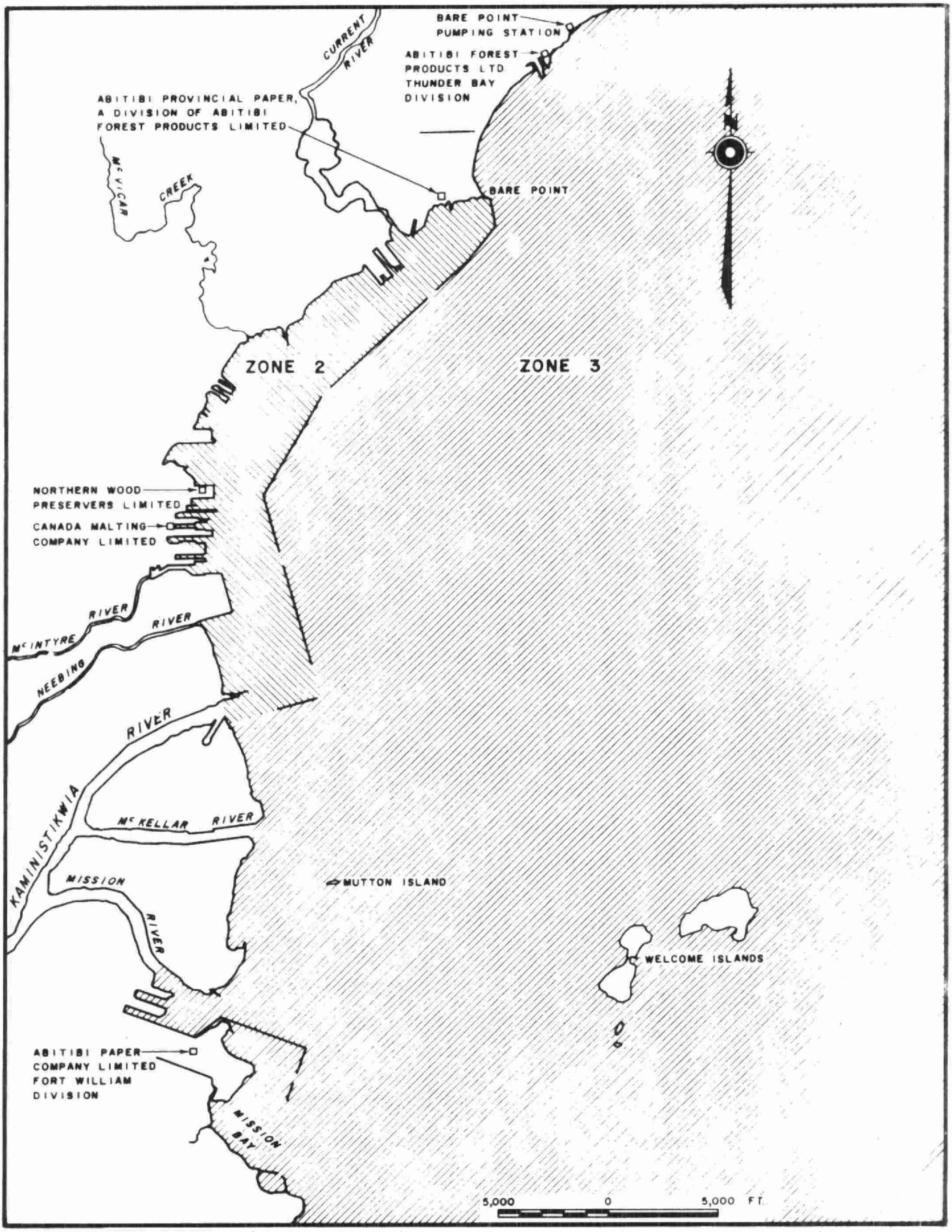

Fig. 2.2 Zones 2 and 3 - Thunder Bay Inner and Outer Harbours

Water temperature, velocity profiles and chemical parameters measured during this study indicate that lake water underlies the river water as far upstream as the Westfort Turning Basin. It was calculated that of the total volume of water flowing in the Kaministikwia River between the Westfort Turning Basin and the confluence of the Kaministikwia and Mission rivers, one half was river water while the other half was Thunder Bay backwash. Downstream from this point to the mouth of the channel, the ratio is generally reduced to one-third or less river water by volume.

Water temperature and chemical parameters suggested it was likely that little mixing occurred between the upper and lower layers of the river. Additional studies are, however, required to define these mixing patterns more accurately.

While a constant velocity in the downstream direction was measured in the upper layer of the river, indications are that translocation of water in the lower layer occurs both in the upstream and downstream direction. This motion, probably best described as "sloshing" is likely the result of fluctuating water levels in Thunder Bay caused by wind seiches. Further studies are required to determine the magnitude and seasonal variations in streamflow patterns in the lower layer of the Kaministikwia River.

Approximately two miles upstream from its mouth, as described earlier, the Kaministikwia River branches into three channels. The flow in each channel was estimated using the volume of each channel and the measured stream velocities. At the time of the August 1970 survey, 42 percent of the flow entered the Bay through the Mission River, 18 percent through the McKellar River and 40 percent through the Kaministikwia River. There is no evidence to indicate that this breakdown would alter significantly under other flow conditions; however, further studies should be performed to define the flow patterns more accurately.

Prior to the August survey, arrangements were made with Ontario Hydro to maintain a constant flow of about 1,000 cfs in the Lower Kaministikwia River for the duration of the water quality survey. Past flow records indicated that a streamflow of this magnitude is typical of August flows during a dry year. An average flow of 1,070 cfs was achieved (measured at Kakabeka Falls).

Currently, Ontario Hydro is attempting to maintain a minimum flow of 600 cfs at Kakabeka Falls, having first established this rate of flow during the summer of 1971. This minimum flow was recommended in a report on the Kaministikwia River Fish Kill (OWRC, August 1970). Ontario Hydro intends to follow this recommendation as a short-term partial solution to the pollution of the lower river, but because of low yields in the headwater reaches some difficulties have been encountered in meeting this guideline.

2.2 POPULATION AND RESOURCE USES

Population

The population of the Lakehead area is concentrated in the City of Thunder Bay with about 12 percent of area residents making their homes in the neighbouring townships. The population of the recently amalgamated City of Thunder Bay is 106,540 based on 1970 assessment data. (Ontario Department of Municipal Affairs, 1971).

Some sub-division development in the area has been rejected by the Ontario Municipal Board because of an OWRC report in 1969 which outlined the inadequacy of the present sewage collection and treatment systems.

It appears that to accommodate further population growth in the urban area, it will be necessary to provide additional serviced districts. Development, according to present plans (Proctor and Redfern, July 1970), will initially be directed at increasing the residential density in the area between the former cities of Port Arthur and Fort William and will later be expanded out to the Lakehead Expressway.

Assuming that the construction of key sewers and treatment facilities will take place in the near future, a 50 percent increase in population could occur in the next twenty years; however, significant growth is not anticipated in the rural areas of the region. This is based on the projections outlined in a report entitled "Design for Development - Northern Ontario", (Ontario Department of Treasury and Economics, 1970).

Land Uses

The primary impetus for the settlement and development of the Lakehead was its location as a trans-shipment point between

raw materials and wheat sources in the prairies and the markets of the east. This had the effect of concentrating development around the harbour facilities of the former cities of Port Arthur and Fort William. Major employers in the area include 25 grain elevators, the Canadian Car Division, Hawker Siddeley Canada Ltd., and the Canadian National and the Canadian Pacific railways, all associated with the above-mentioned transhipment feature. Technological changes, however, in materials handling methods are gradually eroding the employment base of the transportation industry.

The second main factor in the region's development has been the plentiful supply of timber and well-established pulp and paper industry. Four major plants, including the Abitibi Forest Products Ltd., Thunder Bay Division; Abitibi Paper Co. Ltd., Fort William Division; Abitibi Provincial Paper, a division of Abitibi Forest Products Ltd.; and The Great Lakes Paper Company Limited have been established for the exploitation of this resource. Secondary industry has not developed to a significant degree in the Thunder Bay area largely because of the prohibitive distance from major markets in the east. The topography and climate of the Thunder Bay region have limited the major development of agrarian livelihood. Consequently, the residents in rural areas have mainly seeked employment either in urban industry or in the region's logging camps.

Tourism has significantly developed in the Thunder Bay area in recent years. The two nearby provincial parks, Kakabeka Falls and Sibley, are well used by travellers on the Trans-Canada Highway. Also, a municipally operated tent and trailer park, located on the Current River at Trowbridge Falls, sees fairly extensive use during the months of July and August.

In 1971, there were 88,437 registered tourists in Thunder Bay - and many more unregistered. The latter group, particularly, are attracted to the area by the recreational activities available there including skiing, hunting and fishing.

Many inland lakes, including Trout, Surprise and Hawkeye lakes in the Thunder Bay area, are accessible by road and have supported an increasing amount of cottage development for sometime. The proximity of these lakes and beaches to the urban area has relieved the pressure for recreational development on the Lower Kaministikwia River, Neebing River and the harbour area.

The north shore of Thunder Bay has already undergone considerable cottage development. Several beaches are available in this area for public use, notably Wildgoose Park and MacKenzie, Sunnyside and Birch beaches. Chippawa Park, a municipally-operated

recreational area located immediately south of the harbour, provides swimming, boating and campsites.

Water Uses

The waters of the Thunder Bay area must meet a variety of needs some of which are in conflict with each other. The predominant existing uses are domestic and industrial water supply, waste disposal, hydro-electric power generation and commercial shipping. To a much lesser extent, portions of Thunder Bay are used for swimming, boating and angling. In rural areas, streams are used on a limited basis for livestock watering and recreation. Each of these uses is discussed in the section which follows.

Water Supply

a) Municipal

At present, the City of Thunder Bay is supplied by two waterworks, the Thunder Bay North plant (formerly Port Arthur) and Thunder Bay South plant (formerly Fort William). The former is capable of pumping 11 MIGD and withdraws water from Thunder Bay via an intake located at Bare Point. The latter is rated at 12 MIGD and withdraws water from Loch Lomond. Both plants utilize screening and chlorination. The average annual pumpage for the years 1967-1970 for the North and South plants were 5.6 and 7.8 MIGD, respectively.

The two water distribution systems are currently being totally integrated to provide more flexible operation and reliability of supply. It is expected that the modifications in addition to interception will enable existing supplies to meet the projected demands for the next 20 years. In the outlying municipalities, wells are the principal source of water supply.

b) Industrial

The largest individual industrial user of water in the Thunder Bay area is the Ontario Hydro Thermal Generating Station which withdraws approximately 72 to 78 MIGD of cooling water from the mouth of the Mission River, depending on generating requirements as well as the temperature of the river. The pulp and paper

industry is the largest user. Of the four major mills in the area, the following three: Abitibi Forest Products Ltd., Thunder Bay Division; Abitibi Paper Co. Ltd., Fort William Division and the Abitibi Provincial Paper, a division of Abitibi Forest Products Ltd., are located on Thunder Bay Inner Harbour and withdraw 11, 7 and 21 MIGD, respectively, (averages for 1970) of water for cooling and process purposes. The fourth, owned and operated by The Great Lakes Paper Company Limited, is located on and withdraws 68 MIGD of water from the Kaministikwia River. Additional water is obtained from the municipal system.

Several smaller industries withdraw water from one of the above-mentioned sources. Northern Wood Preservers Ltd. and Canada Malting Co. Ltd. also draw water from the Inner Harbour (25,000 IGPD and 0.5 MIGD, respectively), while the chlor-alkali plant of the Dow Chemical Co. of Canada Limited buys treated water from The Great Lakes Paper Company Limited. All industries provide treatment for process water prior to use. Overall, the average pumpage for industrial uses totals about 180 MIGD.

Wastewater Disposal

Some of the watercourses in the Thunder Bay area are used for disposal of treated and untreated wastes from industrial and municipal sources.

The major industrial discharges originated from the pulp and paper mills in the area.

The City of Thunder Bay is served by two primary plants with one discharging to the McIntyre River and the other to the Kaministikwia River. The city has a combined sewer system with numerous outfalls to the nearest watercourse. There are also several unserviced areas within the city. Outlying areas rely on septic tank systems.

Details on the major industrial and municipal waste discharges are presented in Chapter 4.

Electric Power Production

There are two hydro-electric power generating stations on the Kaministikwia River upstream from the study area, one at

Kakabeka Falls and other at Silver Falls. The former station has a capacity of about 24,000 kilowatts while the latter is rated at 45,500 kilowatts. Both installations are owned and operated by the Hydro-Electric Power Commission of Ontario. Flow regulation for these stations is provided primarily by three dams: one on the Kaministikwia River downstream from Dog Lake and upstream from Kakabeka Falls; a second on the Shebandowan River downstream from Shebandowan Lakes; and a third on the Current River at Boulevard Lake.

The Kakabeka Falls plant has four generating units, three of which have a maximum discharge capacity of 390 cfs each and the fourth 640 cfs for a total flow of 1,810 cfs. An earlier arrangement was made to discharge at least 300 cfs over the falls on weekends and holidays and 150 cfs during week days during the tourist season June to September. However, as mentioned earlier, this figure has recently been increased to 600 cfs to provide additional dilution water in the Lower Kaministikwia River.

The Thunder Bay Thermal-Electric Generating Station situated on the north bank of the Mission River at Thunder Bay utilizes cooling water at the rate of approximately 72 to 78 MIGD (134 to 145 cfs).

Another hydro-electric generating station was located on the Current River. This stations had a capacity of 1,800 kilowatts and was operated as a standby during peak demand periods. However, its operation has been discontinued since the fall of 1971.

Commercial and Recreational Fishing

Commercial fishing has seriously declined at Thunder Bay over the past several decades. A fish tainting problem first led to market rejections of local catches by the Federal Fisheries Officer forty years ago; and as of May 1971, pickerel, pike, burbot, yellow perch, white sucker, longrosse sucker and smelt were found to contain average levels of mercury in excess of 0.5 mg/kg. Whitefish, round whitefish, lake trout, rainbow trout, cisco and pink salmon exhibited average levels of mercury below 0.5 mg/kg at that time. However, average levels of mercury in lake trout were found to be 0.81 mg/kg during the summer of 1971. It was therefore necessary to restrict fishing of lake trout in the Thunder Bay area of Lake Superior. At the present time there is no significant recreational fishing in the study area, particularly in the Lower Kaministikwia River mainly because of the low fish populations resulting from impaired water quality.

Furthermore, the proximity of attractive inland lakes including Trout, Surprise and Hawkeye lakes discourages anglers from using the polluted waters of the Kaministikwia River.

In the past, Thunder Bay supported a good commercial fishery for herring, whitefish and several other species. In recent years, it became apparent that fish populations were changing by reduced catches of the more valuable species and larger catches of the coarser varieties such as chub. In addition, inadequate organization of the industry and lack of markets caused a further decline of this industry (Ontario Department of Treasury and Economics, 1970). Currently, commercial fishing, which at one time boasted a 14,000 pound twice-a-year catch, is limited to open waters east of Sibley Point. Owing to problems with mercury and phenolic substances, only fish under three pounds are allowed for marketing, subject to inspection. There is now no commercial fishing permitted in Thunder Bay.

Recreation

Thunder Bay is being increasingly developed for recreational uses. The north shore has considerable cottage development and several public beaches. Most of the east shore lies within Sibley Provincial Park while the area south of the City of Thunder Bay lies within Chippewa Park. Several parks, beaches and other recreational areas are now being planned for development around the bay within the city limits.

Pleasure boating has not developed extensively in the area. Outside the breakwall, Thunder Bay is usually too rough for small boats, while inside the harbour the movement of pleasure craft is restricted by the large volume of commercial shipping moving in and out of Thunder Bay. Only two marinas are located in the Inner Harbour area. Although there is no by-law which prohibits small craft from utilizing the protected waters of the harbour, they still must give right-of-way to the larger vessels, which, through sheer numbers, tend to discourage recreational boating in this area. Furthermore, the aesthetic impairment including high turbidity and dust from grain elevators, and bacteriological contamination have adversely affected this activity as well as the use of the Inner Harbour area for swimming and bathing.

At present, the aesthetically displeasing condition and degraded water quality of the Kaministikwia River limit the number of recreational uses such as boating and swimming. However, the river does have excellent potential for recreational development.

It is one of the few sheltered waterways providing access to Thunder Bay, and, in addition, is navigable from the bay to several miles upstream from the Great Lakes Paper Company Limited. At present, the only recreational boating facilities are a marina near the Mission Channel and a rowing club on the Kaministikwia Channel. There are no public swimming areas on the Lower Kaministikwia River.

Commercial Shipping

Thunder Bay is Canada's western terminus of the St. Lawrence Seaway route, the longest freshwater route in the world that is accessible to ocean-going vessels. The major impetus for growth in Thunder Bay has been related to the importance of the area as a trans-shipment point on the route between the grain growing, oil and gas producing west and the Canadian and foreign markets in the east. It is felt that shipping will continue to play an important role in the economy of the region. Ships are able to navigate up the Kaministikwia River to the Westfort Turning Basin and operate behind the 5-mile breakwall that forms the Thunder Bay Inner Harbour.

Wheat and grain products, iron ore, bulk cargo, paper and wood products,oil and coal are the major commodities handled at Thunder Bay. In 1970, total cargo tonnage exceeded 20 million tons.

Seaplane Bases

Several seaplane bases have been established in Thunder Bay Harbour which provides an excellent natural sheltered waterway for this purpose. The three major ones are the Ministry of Natural Resources Base located at the mouth of the Current River, the Melnick Base located immediately adjacent to the Natural Resources Base and Superior Airway Base located at the Port Arthur Marina. The Natural Resources Base is the largest of these operations, handling six to twelve planes per day.

Log Driving

Although chips and bark may still be trapped along the banks and on the beds of rivers and creeks emptying into Thunder Bay, large scale log driving is no longer carried out in this area.

Currently, trucking operations handle the transportation of logs to the mills, mainly because of the economic advantages offered by this method. Overland vehicles can be utilized throughout the year, require less manpower than did log drives and incur virtually no log losses.

Dredgings Disposal

Sections of the Lower Kaministikwia and Mission rivers are dredged to allow commercial shipping as far upstream as the Westfort Turning Basin (see Table 4.3). In the past, approximately 300,00 cubic yards of sediment dredged each year from the Kaministikwia and Mission rivers were disposed of by the Canada Department of Public Works in Thunder Bay near the Welcome Islands. However, a ruling by the former OWRC has made it necessary to carry out onshore disposal of these materials dredged from the Lower Kaministikwia River Basin.

CHAPTER 3

SURVEY PROCEDURES

3. SURVEY PROCEDURES

3.1 MEASUREMENT OF WASTE INPUTS

In-plant surveys of all major industries discharging to the waters in the study area were conducted during August 1970. The results of these studies and data summaries submitted to the OWRC by the industries were used for calculating the industrial waste inputs.

The municipal waste inputs from the two sewage treatment plants were based on plant records complemented by additional samples collected during the water quality investigations. The waste loadings from the Clarke Street and Lillian Street combined sewers were estimated on the basis of population served.

The results of grab samples and spot flow measurements were used to obtain the waste inputs from all other sewers.

The indirect waste inputs via streams flowing into the Thunder Bay Harbour area and Thunder Bay were based on streamflow records and water quality measurements taken near the mouths of the rivers during monitoring runs carried out from 1967 to 1970.

Discussion of the waste sources and summaries of wastewater loadings are presented in Chapter 4. Detailed analytical results are presented in Appendix B.

3.2 WATER QUALITY EVALUATION

An intensive study of the Kaministikwia River upstream from The Great Lakes Paper Company Limited downstream to the mouth of the river was conducted from August 5 to August 30, 1970. This study included measurements of the physical characteristics of the stream, *in situ* measurements of benthic oxygen demand, collection and analysis of sediment samples and examination of chemical and bacteriological water quality.

In an effort to model the response of the river to organic wastewater discharges, an intensive water quality study was conducted over a 72-hour period (August 11 to 14). Seventeen sampling ranges (shown on Figure 3.1) were selected for this purpose. These were sampled on an around-the-clock basis at regular intervals.

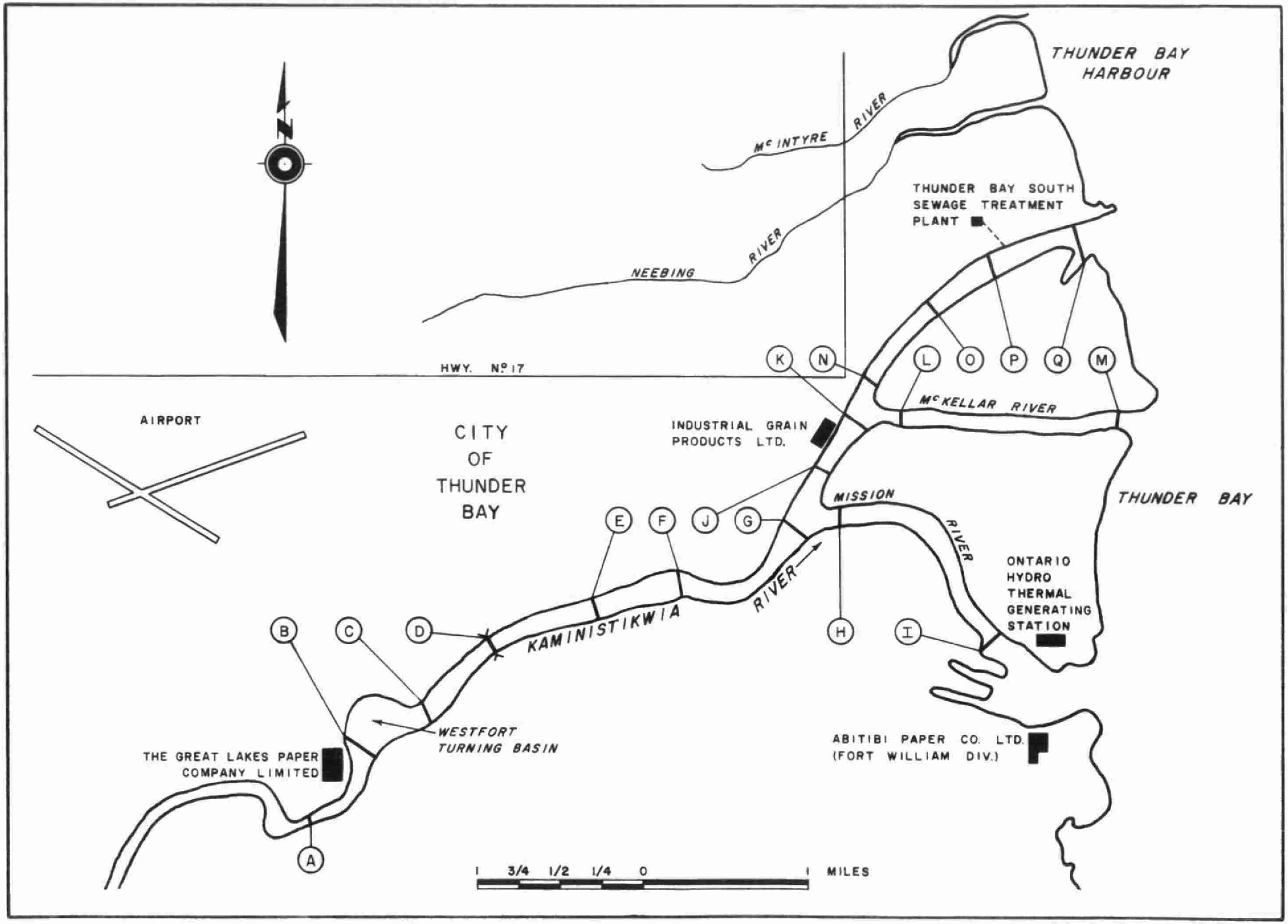

Fig. 3.1 Sampling ranges (A-Q) - Zone 1, Lower Kaministikwia River

The water quality evaluation of the Thunder Bay Harbour and adjacent Thunder Bay area was conducted from August 5 to 30, 1970. Samples were collected from 69 locations which are shown on Figure 3.2. Most of these were sampled five times while some were sampled on four occasions.

The samples were analyzed for biochemical oxygen demand (BOD_5), solids, nutrients, phenolic substances, colour and bacterial levels. The bacteriological analyses and analyses for BOD_5 and phenolic substances were conducted at the OWRC laboratory in Thunder Bay. All other analyses were performed in the OWRC laboratory in Toronto.

During each sampling run, some dissolved oxygen and temperature levels were measured in the field using dissolved oxygen meters.

Sediments

Sediment samples (cores and dredging) were collected from the Kaministikwia River from the reach extending from the Hwy. #61 Bridge (upstream from The Great Lakes Paper Company Limited) downstream to the mouth of each of the three channels. Following visual examination, the sediments were analyzed for organic material content (volatile solids) and metals. In addition, benthic oxygen uptake rates were measured directly downstream from the turning basin.

A discussion of findings and tabulation of analytical results are presented in Chapter 4 and Appendix B, respectively. Details on the modelling are presented in Appendix A.

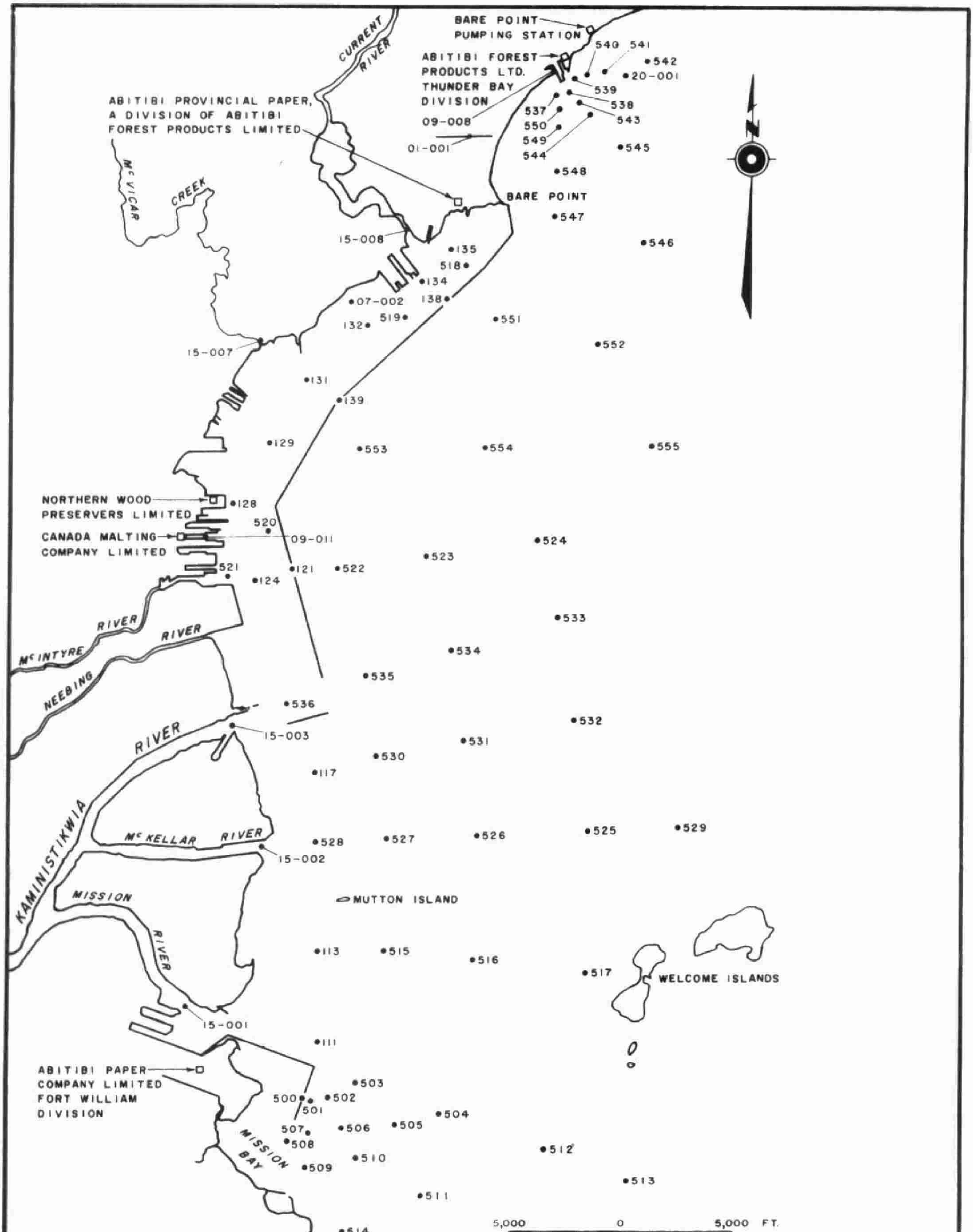

Fig. 3.2 Sampling locations - Zones 2 and 3

CHAPTER 4

FINDINGS AND DISCUSSIONS

4. FINDINGS AND DISCUSSIONS

4.1 WASTE SOURCES

The waste inputs and their effects on water quality are discussed in this chapter. The study area was sub-divided arbitrarily into three zones which were described in Section 2.1 of Chapter 2.

4.1.1 Zone 1 - Kaministikwia River Basin

The Kaministikwia River Basin in the study area receives wastewater discharges from five major industries, one municipal sewage treatment plant and 14 municipal sewers. The major waste inputs are summarized in Table 4.1. Each major waste source is discussed below.

Industrial Wastes

- The Great Lakes Paper Company Limited

The Great Lakes Paper Company Limited operates a pulp and paper mill with facilities to produce newsprint, groundwood, sulphite and bleached and unbleached kraft pulp. Newsprint production (including groundwood, sulphite and kraft pulps) totals 400,000 tons per year. In addition, the kraft mill has a capacity of approximately 210,000 tons per year of bleached pulp. The paper machines and the groundwood and sulphite pulp mills operate six days per week and the kraft mill seven days per week.

Process water is taken from the Kaministikwia River upstream from the mill and approximately 68 MIGD of wastewater is discharged to the Kaministikwia River. Of this flow, approximately 25 MIGD has been utilized by the kraft mill and has received

TABLE 4.1 SUMMARY OF WASTEWATER LOADINGS TO ZONE 1 - LOWER KAMINISTIKWIA RIVER, 1970 AVERAGE

Source	Flow (MIGD)	BOD_5	Solids		Phosphorus as P		Total Nitrogen as N	Mercury Hg	COD	Sulphates SO_4
			Total	Suspended	Total	Soluble				
Thunder Bay South STP	5.7	4,400	21,000	4,500	350	150	900	-	-	-
Great Lakes Paper Company Limited	56.8	309,000	1,391,000	156,000	310	70	1,994	-	1,190,000	68,000
Dow Chemical of Canada Ltd.	4.15	-	-	-	-	-	-	0.3	-	-
Industrial Grain Products Ltd.	.33	25,000	38,000	12,000	130	92	330	-	33,000	-

Loadings in lbs/day

primary treatment (screening and neutralization) before discharge to the river via a submerged effluent diffuser. A portion of the kraft mill wastes also receives clarification while bleaching wastes do not. Based on the waste loadings measured during the August study period (Table 4.2) and average daily inputs for 1970, this source accounted for 90 percent of the organic loading and 95 percent of the suspended solids discharged to the river. In addition, the mill discharged significant quantities of phenolic substances to the river but representative data on the loading could not be obtained during the study.

Sanitary wastes from the kraft mill are separated from process wastes and discharged to septic tanks while those originating from the newsprint mill are combined with the process wastewater discharges.

The Great Lakes Paper Company Limited has proposed a comprehensive waste treatment program and waste recovery systems to be implemented by the end of 1974 at an estimated cost in excess of $10 million. The Company has already installed a major collection sewer and pumping station, two clarifiers and sludge dewatering facilities as the first stage in the waste treatment program. As part of the overall program, the company plans to treat all sanitary wastes from the mill. The new clarifier/dewatering facilities were in place by September 1971 and, after the implementation of several design changes, are now operating as planned. The system is removing approximately 60 tons per day of suspended solids from the newsprint mill effluent.

- Industrial Grain Products Limited

This industry produces wheat gluten and starch, utilizing approximately 120 tons per day of flour. The total waste discharge from the operation is approximately 0.33 MIGD.

Portions of waste effluent from the company's processes are currently discharged untreated to the Kaministikwia River. These wastes are very high in BOD_5 and nutrient materials (Table 4.1).

The company is currently revising its process by recirculating many wastewater streams into the process for further product recovery. Evaporators will be used to concentrate the wheat gluten and starch in waste streams in order that these products may be recovered. It is planned to discharge streams which cannot be recycled to the municipal sewer system, thus eliminating the discharge of contaminated wastewater from the

TABLE 4.2 SUMMARY OF WASTEWATER LOADINGS TO ZONE 1 - LOWER KAMINISTIKWIA RIVER, AUGUST 10-14, 1970

	Great Lakes Paper Company Limited	Industrial Grain Products Limited
Flow (MIGD)	65.6	0.3
BOD_5 (tons/day)	169.5	10.8
Solids (tons/day)		
Total	703.5	7.7
Suspended	82.5	3.9
Dissolved	621.5	3.8
Phosphorus as P (lbs/day)		
Total	363	88.5
Soluble	87	79.5
Nitrogen as N (lbs/day)		
Free Ammonia	212	2.1
Total Kjeldahl	2,443	297
Nitrite	25	0.06
Nitrate	11	0.05
Sulphate (tons/day)	32	-
Phenolic substances (lbs/day)	55.6	-

plant to the river. If the quality of these discharges does not comply with the industrial waste by-laws, pre-treatment may be required. Part of the new recycle system is already in operation. The municipal interceptor sewer, which will receive the wastewater which cannot be recycled, is currently under construction and should be completed by the end of 1972.

- Dow Chemical of Canada Ltd.

The chlor-alkali plant of Dow Chemical of Canada, produces chlorine and caustic soda by the electrolytic decomposition of rock salt using the mercury cell process.

In the past, mercury has escaped to the river as a constituent of the wastewaters from this process; however, these wastewaters now are either recycled into the process or directed to retention ponds (two in series), where chemicals are added to precipitate mercurial compounds before discharge to the river. A holding tank has been installed in the event of a major spill. Sludge from the retention ponds (mainly brine sludges) is disposed of on land. Prior to these improvements the mercury treatment system was limited to one settling pond for brine sludges. This pond was constructed with the plant in 1967.

During 1970, the daily discharge of mercury steadily decreased from 1.2 pounds per day in January, prior to the improvements in the mercury treatment system, to 0.055 pounds per day in December, at which time the treatment system was fully operational. The average daily discharge of mercury for 1970 was 0.3 pounds per day (Table 4.1) which amounts to a loss of approximately 110 pounds per year. In-plant changes have further reduced the mercury losses resulting in an average loss of less than 0.036 pounds per day in 1971.

- Canadian National Railways

At the time of the survey, untreated oily wastes from the Canadian National Railway (Neebing) Yard were being discharged to the Kaministikwia River about 1.5 miles upstream from the Westfort Turning Basin. The OWRC approved plans for the installation of pollution control facilities including drip trays and two oil separators. It is expected that installation of these facilities will be completed during the fall of 1972.

- Canadian Pacific Railway

Runoff from the CP marshalling yards is directed to an oil separator prior to discharge to the Kaministikwia River via two outfalls. At the time of this survey no discharge was observed.

Other Industrial Inputs

A number of other industries are also located along the river but in general, the wastewater discharges from these sources are considered to be relatively small in comparison to the major municipal and industrial wastewater sources. Nevertheless, it would be desirable to examine their waste disposal practices to ensure that adequate control measures are being provided.

Municipal Wastes

The Thunder Bay South sewage treatment plant (formerly the Fort William STP) is a primary treatment plant with a capacity of 6 MIGD. Past plant policy called for the effluent to be chlorinated during the summer months and discharged to the Kaministikwia River near its mouth. Now, however, effluent chlorination is practised on a year-round basis. The BOD_5 discharge of 4,400 pounds per day (average for 1970, Table 4.1) from the STP is small in comparison to waste discharges from industry in the area, nevertheless, the plant is a major source of phosphorus and nitrogen in the Thunder Bay area.

Both the Thunder Bay South STP and the Thunder Bay North STP (the latter discharges to the McIntyre River) now are operating at or above their hydraulic capacities. The consulting firm of Proctor and Redfern was retained in order to prepare a report (Proctor and Redfern, February 1971) on the construction of one 24 MIGD plant to serve the entire City of Thunder Bay. The new facility would be located at the site of the present Thunder Bay South STP, with the other existing treatment plant serving only as a pumping station. Wastes would receive primary treatment and chlorination prior to discharge. An earlier preliminary design report by the consulting engineering firm of W.L. Wardrop and Associates recommended that an interceptor sewer (W.L. Wardrop and Associates, 1958) be constructed in stages along the bank of the Kaministikwia River to divert all sanitary wastes, currently being discharged to the river, to the municipal STP. This recom-

mendation has been reviewed by the municipality and it is expected that the interception of all outfalls will be completed by 1978.

Other Inputs

1) Dredgings Disposal

Because of the large volume of settleable materials entering the Kaministikwia and Mission river, sections of these watercourses require maintenance dredging on a regular basis to allow shipping as far upstream as the Westfort Turning Basin. In the past, the Thunder Bay Canada Department of Public Works has billed the contributing mill for half the cost of dredging since it has been determined that dredgings downstream from the mill consisted of approximately 50 percent wood fibres and 50 percent silt.

Overall, approximately 330,000 cubic yards of sediment are dredged from these river channels and the harbour area each year. A summary of the dredging quantities for Zones 1 and 2 is presented in Table 4.3.

The practice of dredging on a regular basis has several disadvantages. Bottom sediments or sludges have been found to contain organic oxygen-consuming materials, mercury, other heavy metals and oil and grease in several instances. During dredging many of these contaminants can be resuspended from the sediment and translocated downstream. For example, resuspended oxygen-consuming materials and other contaminants can be carried downstream causing further oxygen depletion, interfering with the aquatic community. In addtion, mercury and other toxic metals in the sediments can be accumulated by aquatic biota including fish which could, if ingested, create a health threat to man.

Prior to 1970, these sediments were disposed of in Thunder Bay near the Welcome Islands, however, since then the OWRC restricted open lake disposal of dredgings containing more than 10 percent volatile solids or other pollutants such as mercury, heavy metals, oil, grease, oxygen-consuming wastes, etc. This ruling has made it necessary to use onshore disposal, as described earlier, for material dredged from the Westfort Turning Basin and from the Kaministikwia River several miles downstream from the Turning Basin. Analytical results for sediments collected from this area are presented and discussed in Chapter 4, Section 4.2.1 - Sediments.

TABLE 4.3 SUMMARY OF DREDGING QUANTITIES, ZONES 1 AND 2 *

Year	Total Quantity	Westfort Turning Basin	Kaminis-tikwia River	Mission River	Lakehead Harbour
1958	423,338	75,055	6,981	-	341,302
1959	167,677	129,922	37,755	-	-
1960	527,904	-	-	264,392	263,512
1961	279,675	178,117	-	-	101,558
1962	487,871	-	264,578	52,184	171,109
1963	317,404	185,366	53,714	78,324	-
1964	375,038	-	138,231	100,373	136,434
1965	448,556	137,203	34,509	214,350	62,753
1966	238,265	-	118,571	120,344	-
1967	181,586	142,536	30,287	20,000	17,160
1968	278,106	-	-	-	-
1969	412,965	255,520	-	136,945	20,500
1970	95,530	-	71,000	-	24,530
Proposed for 1971	350,000	171,000	49,000	-	130,000

* Cubic Yards

Currently, little maintenance dredging is carried out in Thunder Bay Inner Harbour. Sediment is removed only on an as-needed basis, usually either to enlarge a slip or remove a recently formed shoal.

2) Snow Disposal

Preliminary investigations by the OWRC during the winter season of 1968-69 and 1969-70 at snow dumping areas within the City of Thunder Bay showed that dumped snow contained potential water pollutants (OWRC, 1970). It is common practice in the City of Thunder Bay to remove snow from various areas within the City and truck this material to sites adjacent to local watercourses or to sites located upon the ice which has formed on local watercourses.

Surveys revealed that the Marina snow dump, located immediately southwest of McVicars Creek adjacent to Thunder Bay Inner Harbour, and the Mission snow dump, located on the east bank of the Kaministikwia River about 800 feet upstream from the McKellar River, contained significant concentrations of BOD_5, suspended solids, turbidity, chlorides and phenolic substances (Table 4.4). It is estimated that virtually all of the materials in the snow from the Marina dump and approximately 75 percent of the Mission dump snow materials eventually reach the adjacent watercourses directly by runoff when melting occurs.

TABLE 4.4 SNOW SAMPLE ANALYSIS				
Parameter	Port Arthur Marina Dump		Mission Island Dump	
	Concentration mg/l	Total Annual Runoff * lbs	Concentration mg/l	Total Annual Runoff lbs
BOD_5	36	503	62	123
Suspended Solids	4,500	60,740	2,272	4,500
Total Phosphorus	6.9	96	4.3	11
Chlorides	241	3,367	288	757
pH	6.7	-	7.3	-
Phenolic Substances	16 μg/l	0.02	12 μg/l	0.003
Cyanide	0.01	0.14	0.025	0.06
Lead	2	28	3.61	9.5

* *The above loadings which enter Thunder Bay Harbour during spring break-up from the Marina dump have been estimated using an annual runoff of 1.4 million gallons.*

Waste loadings to the Kaministikwia River from the Mission dump were based on the following annual spring runoffs:

0.198 million gallons for BOD_5 and suspended solids (assume 25 percent of solids and BOD_5 removed on land)

0.263 million gallons for all other parameters.

4.1.2 Zone 2 - Thunder Bay Inner Harbour

Thunder Bay Inner Harbour receives direct waste inputs from three industries, one municipal sewer and indirect industrial and municipal wastes via three streams. Each waste source is discussed in the sections which follow.

Industrial Wastes

- Abitibi Provincial Paper, A Division of Abitibi Forest Products Ltd.

This mill produces fine papers from groundwood and sulphite pulps and is the largest source of industrial wastes discharging to Thunder Bay Inner Harbour, accounting for 89 percent of the total BOD_5, 81 percent of the total COD and 51 percent of total solids loadings (on the basis of both municipal and industrial loadings measured during this survey). The mill wastewaters which consist of groundwood, woodroom, sulphite and paper mill wastes are treated in a zig-zag sedimentation lagoon prior to discharge to the northern end of the harbour. Sanitary wastes from the mill are also discharged to the lagoon system. Details on the wastewater loadings are presented in Table 4.5. Loadings for phenolic substances were not included in Table 4.5 due to lack of representative data.[1]

Treatment facilities, costing $600,000 for the mill were approved by the OWRC in January 1971. These included a 75 foot diameter primary mechanical clarifier, a vacuum sludge thickener, a collection tank and sewer modifications. The effluent from this system will discharge to the existing lagoon. The final effluent is expected to meet this Ministry's criterion for suspended solids of less than 50 mg/l. The new facilities became operational in April 1972.

- The Canada Malting Company Limited

In August 1970, the Canada Malting Company Limited discharged a waste load of 3.2 tons of BOD_5, 4.5 tons of COD and 1.8 tons of total solids per day into the end of the slip immediately north of the Saskatchewan Pool Elevator Number 7.

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1 *It should be noted that although representative data could not be obtained during this study, the pulp and paper mills are known to discharge significant quantities of phenolic substances. This industry is, therefore, believed to be responsible for the increases in the levels of phenolic substances in both Zones 2 and 3.*

TABLE 4.5 SUMMARY OF WASTEWATER LOADINGS TO ZONE 2 - THUNDER BAY INNER HARBOUR, 1970 AVERAGE

Source	Flow MIGD	BOD_5	Solids Total	Solids Suspended	Phosphorus as P Total	Phosphorus as P Soluble	Total Nitrogen as N	COD	Sulphates SO_4
Abitibi Provincial Paper, A Division of Abitibi Forest Products Ltd.	20.8	101,400	202,000	23,600	42	2	418	279,000	27,000
Northern Wood Preservers Limited	.007	3	16	4	-	-	-	18	-
Canada Malting Company Ltd.	0.5	6,400	3,500	1,095	36	26	75	8,900	-
Clarke Street Combined Sewer *		736	3,220	1,140	48	25	160	-	-

* Population estimate 6,700 people at 100 gpd

Loadings in lbs/day

The company's wastewater treatment is limited to rough screening of solids. However, the proposed abatement program of the Canada Malting Company Limited features the discharge of all wastewaters to a city sanitary sewer which is to be installed sometime in the future. These wastes, of course, should meet industrial waste by-laws prior to discharge to the municipal system. The sanitary sewer construction is to be started in 1978; however, this date is tentative.

- Northern Wood Preservers Company Limited

Waste treatment facilities of Northern Wood Preservers Company Limited appear, based on survey findings, to be adequate. The company utilizes an activated sludge plant. During the August 1970 survey, it was found that a relatively small load of pollutants originated from this plant. However, the company uses a section of the harbour for storage of logs which has contributed to water quality and aesthetic impairment due to bark losses. Details on the discharge from this waste source are presented in Table 4.5.

Other Industrial Sources

Several other industries are also located along the shoreline of Zone 2, but detailed investigations of these sources were not made in the course of this survey. Since, in general, the wastewater discharges from these sources are considered to be relatively small. It would be desirable, however, to examine their waste disposal practices to ensure that adequate controls are being provided.

Municipal Wastes

- Clarke Street Combined Sewer*

It was estimated that this sewer discharged 670,000 IGPD of domestic wastes in 1970 (6,700 people rated at 100 IGPD each). A breakdown of the wastewater loadings from this waste

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* *The Clarke Street sewer has, since the August 1970 survey, been connected directly to the municipal interceptor sewer.*

source is given in Table 4.5. Although this sewer accounted for only approximately 4½ percent of the total solids loadings to Zone 2, it was one of the major sources of bacterial contamination discharging to the harbour.

Other Inputs

1) Tributaries

This zone also receives wastes from McVicar Creek and the McIntyre and Neebing rivers. The sampling point in the McIntyre River was located downstream from the outfall of the Thunder Bay North sewage treatment plant and therefore the loading estimates for this river include the STP load. It was estimated that the municipal wastes entering the McIntyre River accounted for at least 75 percent of the total BOD_5 and suspended solids in the river at its point of discharge into the harbour. Average daily loadings for the STP for the year 1970 are presented in Table 4.6.

TABLE 4.6

DAILY LOADINGS FROM THUNDER BAY NORTH STP*
1970 Average

(lbs/day)

Flow (MIGD)	BOD_5	Total Solids	Suspended Solids	Total Phos-phorus	Soluble Phos-phorus	Am-monia	Total Kjeldahl
5.5	4,100	22,000	4,500	300	110	570	940

* *These loadings are based on treated wastes and do not include any by-pass discharges which are estimated to be 1 MIGD (1971).*

4.1.3 Zone 3 - Thunder Bay Outer Harbour

The Thunder Bay Outer Harbour receives discharges from two industrial waste sources, three river inputs and one combined municipal sewer and also water through the Inner Harbour breakwall.

The Thunder Bay Thermal Generating Station of the HEPCO, located on the southeast end of Mission Island, draws its cooling water from the Mission River and discharges it to Thunder Bay close to the mouth of the river. Each waste source is discussed in sections which follow.

Industrial Wastes

- Abitibi Forest Products Ltd., Thunder Bay Division

This mill produces newsprint from groundwood and sulphite pulp and discharges approximately 10.7 MIGD (1970) of wastewater to the northern part of Zone 3. Prior to discharge the wastes are treated in a lagoon system to remove suspended solids. Details on the wastewater characteristics and loadings are presented in Table 4.7. Sanitary wastes from this mill are segregated from process wastes and discharged to a septic tank system.

Currently, the effluent from this mill meets this Ministry's criterion for suspended solids of less than 50 mg/l. The mill's lagoon system includes two parallel primary ponds each with a retention time of 12 hours followed by a polishing lagoon which adds a further 24 hours of retention. This system was completed in November 1970 at a cost of $200,000. However, due to an odour problem in the polishing lagoon, a dyke was breached to by-pass this lagoon resulting in a discharge to Lake Superior after retention in the primary ponds only. The effluent still meets this Ministry's criterion for suspended solids of less than 50 mg/l.

- Abitibi Paper Company Ltd., Fort William Division

This mill produces newsprint from sulphite and groundwood pulps and discharged an average (1970) of 10 MIGD to Thunder Bay at a point immediately south of the mouth of the Mission River.

Approximately 1 MIGD originating from the woodroom operations is treated in two sedimentation lagoons in series prior to discharge to Thunder Bay. In November 1971, the mill installed a third lagoon to handle woodroom effluent. This lagoon is in parallel to the original two sedimentation lagoons.

At the time of this study, the remaining 9 MIGD was discharged through the main mill sewer to another sedimentation lagoon

TABLE 4.7 SUMMARY OF WASTEWATER LOADINGS TO ZONE 3 - THUNDER BAY OUTER HARBOUR, 1970 AVERAGE

Source	Flow MIGD	BOD_5	Solids		Phosphorus as P		Total Nitrogen as N	COD	Sulphates SO_4
			Total	Suspended	Total	Soluble			
Abitibi Forest Products Ltd., Thunder Bay Division	10.7	29,000	76,000	18,000	37	34	592	160,000	20,800
Abitibi Paper Co. Ltd., Fort William Division	6.9	51,300	126,000	6,200	29	15	128	185,000	23,700
Lillian Street Combined Sewer *	0.53	584	2,540	900	38	20	127	-	-

* Population estimate 5,300 people at 100 gpd (does not include storm runoff)

Loadings in lbs/day

system, consisting of two lagoons in parallel, and thence to Thunder Bay. A third lagoon will be constructed in 1972 in series to the second lagoon to treat the main mill discharges. This third lagoon will allow for effective effluent treatment while sediment is dredged from the original lagoon system. The final effluent is expected to meet this Ministry's criterion for suspended solids of less than 50 mg/l.

The industrial waste loadings from the two paper mills represent 50 percent of the BOD_5 input to the area outside the harbour, however, they contribute only 13 percent of the total solids load, due to the significant solids input entering via the Kaministikwia River system.

- Thunder Bay Thermal Generating Station, HEPCO

Ontario Hydro's generating station used approximately 72-78 MIGD of water for cooling purposes in 1970. Aside from the thermal input, no significant waste inputs resulted from this discharge. The thermal effects of the plant's effluent on Thunder Bay are discussed under the section entitled Environmental Effects.

Other Industrial Sources

There are a few other minor sources of industrial wastes discharging into Zone 3 but these were not examined during this study. Nevertheless, it would be desirable to examine their waste disposal practices to ensure that adequate control measures are being provided.

Municipal Wastes

The Lillian Street combined sewer was estimated to discharge 530,000 IGPD in 1970 (5,300 people each rated at 100 IGPD). This may be a conservative estimate since storm sewer runoff is not included.

Loadings in 1970 for this waste source are presented in Table 4.7. Originally a municipal settling tank was installed to treat wastes being handled by this sewer. However, investigations by the OWRC established that little or no treatment of wastes was resulting from this settling tank.

Other Inputs

The estimated flows and waste inputs into the bay via the Kaministikwia, McKellar and Mission rivers are presented in Table 4.8. The BOD_5 and total solids loadings for these amounted to 107,600 and 942,462 pounds per day, respectively.

4.2 WATER QUALITY EVALUATION

4.2.1 Zone 1 - Lower Kaministikwia River

The discharges of industrial and domestic wastewaters seriously impair the quality of the Kaministikwia River upstream from the Westfort Turning Basin to Thunder Bay. The following sections describe the water quality as observed during the August 1970 survey and compare these findings to conditions measured over the past four years from data collected during the routine water quality monitoring program.

Biochemical Oxygen Demand - Dissolved Oxygen Variation

At the time of the study, the BOD_5 discharge (154.5 tons per day) from The Great Lakes Paper Company Limited mill increased the average BOD_5 level in the Kaministikwia River from 3.1 mg/l upstream from the plant outfalls to 57.7 mg/l downstream from the outfalls. Similarly, BOD_5 levels were found to increase from 28.1 mg/l to 36.5 mg/l downstream from the point of discharge of organic wastes (12.5 tons per day in 1970) from Industrial Grain Products Limited. The Thunder Bay South Sewage Treatment Plant, which discharges 2.2 tons per day of BOD_5, did not significantly increase the overall BOD_5 level in the river; however, slightly higher concentrations did occur along the north shore of the Kaministikwia River downstream from this discharge.

In August 1970, BOD_5 levels were significantly higher than the mean conditions observed since 1967. This trend can be seen in the biochemical oxygen demand profiles presented in Figure 4.1. Within the first two miles downstream from the mill of The Great Lakes Paper Company Limited, BOD_5 concentrations were four to five times above average levels of the monitoring data. Similarly, near the mouths of the Mission and McKellar rivers, two to threefold increases were measured. At no time did BOD_5 concentrations from the monitoring data exceed the August survey levels.

TABLE 4.8 SUMMARY OF WASTEWATER LOADINGS TO THUNDER BAY OUTER HARBOUR FROM THE KAMINISTIKWIA RIVER SYSTEM, AUGUST 11-13, 1970

PARAMETER	KAMINISTIKWIA RIVER		MCKELLAR RIVER		MISSION RIVER		TOTAL
	lbs/day	mg/l	lbs/day	mg/l	lbs/day	mg/l	
Flow (cfs)	430		190		450		1,070
BOD_5	47,136	20.3	12,106	11.8	48,357	19.9	107,600
Total Nitrogen as N	1,528	0.658	526	0.513	1,106	0.455	3,160
Total Phosphorus as P	195	0.084	60.5	0.059	97	0.040	353
Solids							
- Total	357,588	154	142,614	139	442,260	182	942,462
- Suspended	13,932	6	5,130	5	14,580	6	33,642
Chlorides	23,127	9.96	9,234	9.00	29,889	12.30	62,250
Phenolic Substances	21	9 (μg/l)	9.2	9 (μg/l)	22	9 (μg/l)	
Turbidity (JTU)		4.6		5.1		5.8	5.2

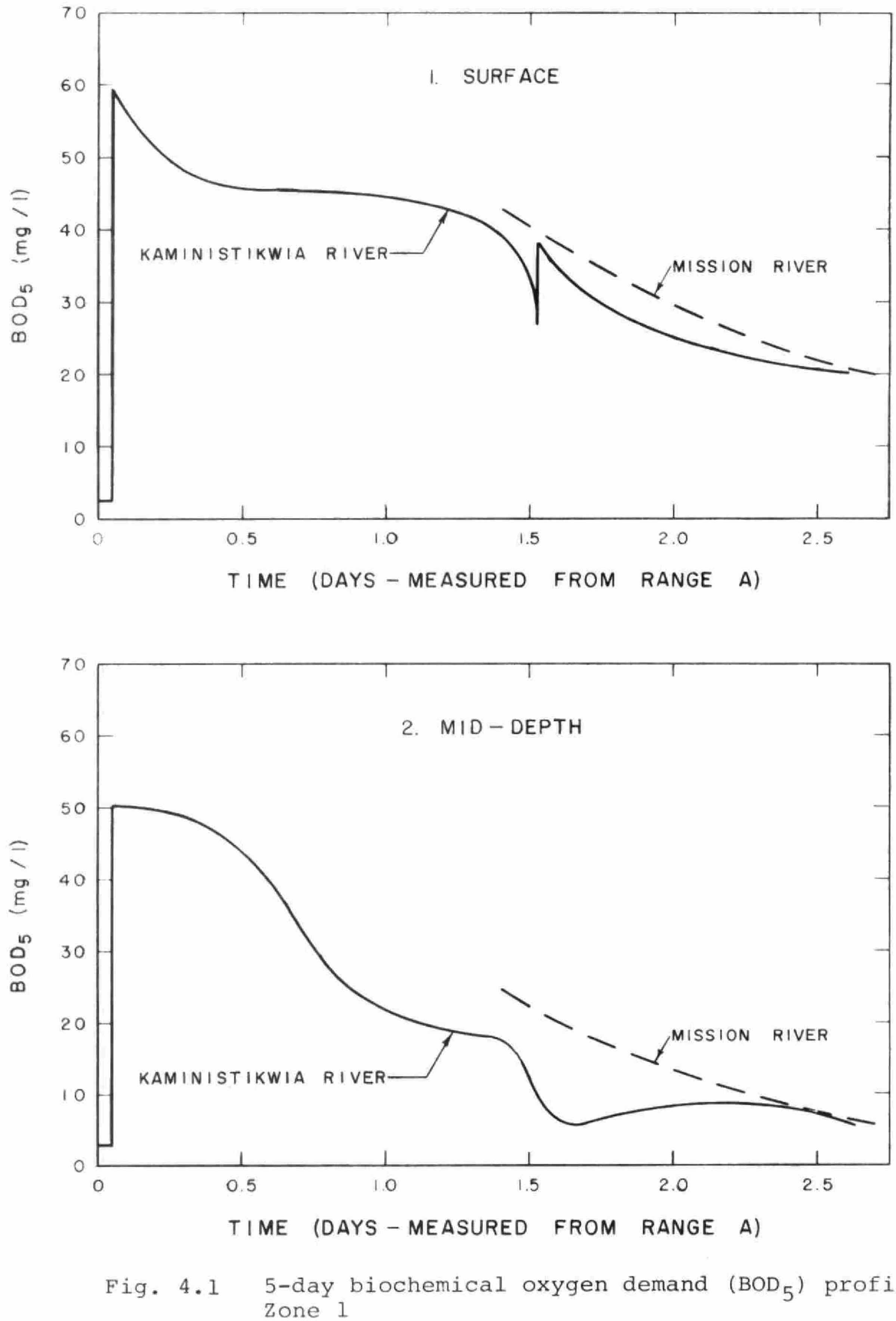


Fig. 4.1 5-day biochemical oxygen demand (BOD_5) profile - Zone 1

The differences between the survey and monitoring data are probably due to variations in streamflow and the resultant dilution of waste inputs. The survey data were collected during a relatively low flow period when dilution would not be as great as during the rest of the year.

BOD-DO Model

A mathematical model was developed relating deoxygenating waste inputs (BOD) and bottom sediments to resulting dissolved oxygen (DO) levels in the Kaministikwia River. Deoxygenating and reaerating rates were estimated using chemical and physical data collected during the summer. The rates and their definitions are presented in Appendix A. The reaction rate coefficients used in the model are based on the 1970 survey conditions and it would be desirable to update the model after a substantial portion of the organic wastewater loading has been removed.

Figure 4.2 shows the BOD_5 loadings for minimum dissolved oxygen levels of 1, 3 and 5 mg/l at streamflows ranging from 350 to 1,000 cfs. The graph may be used to find the organic wastewater loading capacity for a specific set of conditions (e.g. minimum DO level - 5.0 mg/l, summer drought flow - 350 cfs, loading capacity 8,000 pounds BOD_5 per day).

The graph may also be used to estimate resultant minimum DO levels for a specific organic waste loading and streamflow condition (e.g. BOD_5 loading - 60,000 pounds per day, streamflow 800 cfs, minimum resultant DO - 3 mg/l). A constant streamflow of 1,070 cfs was maintained by Ontario Hydro in the Kaministikwia River throughout the survey. The calculated low flow of 350 cfs (7-day average with a 5 percent chance of occurrence) was purposely exceeded to maintain aerobic conditions in the lower end of the study reach.

Currently Ontario Hydro is attempting to maintain a minimum flow of 600 cfs at Kakabeka Falls which, using Figure 4.2, corresponds to a loading capacity of 19,000 pounds BOD_5 per day at a dissolved oxygen level of 5.0 mg/l. To meet this loading limit, the BOD_5 loading from The Great Lakes Paper Company Limited would have to be reduced by over 90 percent if the total river capacity were allotted to this industry. However, as discussed above, the loading limit is dependent upon streamflow and the availability of additional streamflow augmentation should be examined.

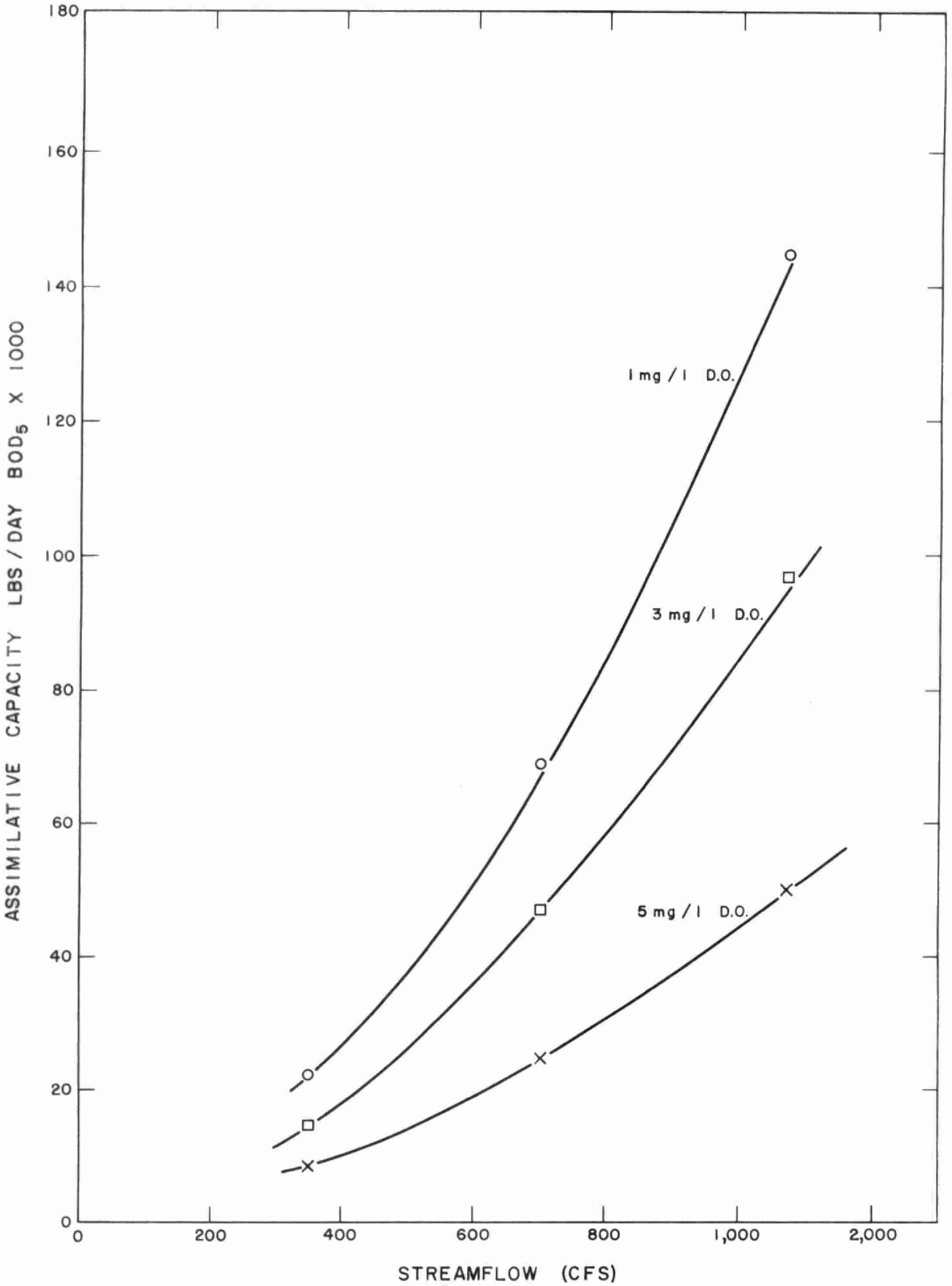


Fig. 4.2 Assimilative capacity of the Kaministikwia River downstream from Westfort Turning Basin

Dissolved oxygen levels (see Figure 4.3) in the surface waters of the Kaministikwia River demonstrate the classical response of a river to the discharge of oxygen-consuming wastes. Levels were about 80 percent saturation in the vicinity of the outfalls of The Great Lakes Paper Company Limited and then began to drop as organic materials were oxidized. Approximately one-half mile upstream from the mouth of the Kaministikwia River (about five miles downstream from the outfalls), dissolved oxygen in the surface waters was almost depleted. Downstream from this point to the lake some recovery was indicated with dissolved oxygen levels climbing back up to 50 to 60 percent saturation at depths of 10 feet and lower.

At depths of 10 and 20 feet, the low concentration of dissolved oxygen can be attributed to the effects of suspended and dissolved oxygen-consuming wastes, benthic oxygen demand, the lack of mixing of lake water with river water and the subsequent lack of reaeration. Oxygen concentrations in the bottom 10 feet of river water were almost depleted immediately downstream from the mill and for about three miles downstream, however, recovery of oxygen was evident in the river's downstream reaches. The concentration of BOD_5 was also found to be lower in the downstream sections of the river. It is likely that some mixing with lake water occurs at this point. Generally, the dissolved oxygen levels determined during the August 1970 survey are representative of concentrations measured during past summer periods.

Dissolved and Suspended Solids

The level of dissolved solids, as found in August 1970, increased from 98 mg/l upstream from The Great Lakes Paper Company Limited to 215 mg/l directly downstream from the mill outfall and remained at this level downstream as far as the junction of the Kaministikwia and McKellar rivers. Immediately upstream from the mouths of each of the Kaministikwia, McKellar and Mission rivers, dissolved solids levels in the surface water dropped to 150, 135 and 171 mg/l, respectively.

On the other hand, water quality monitoring data indicated that average dissolved solids levels over the past four years were significantly lower than August 1970 survey determinations. These data showed that upstream from the mill, dissolved solids averaged 64 mg/l. Downstream from the mill, the level increased to about 100 mg/l and remained at this concentration throughout the lower reaches.

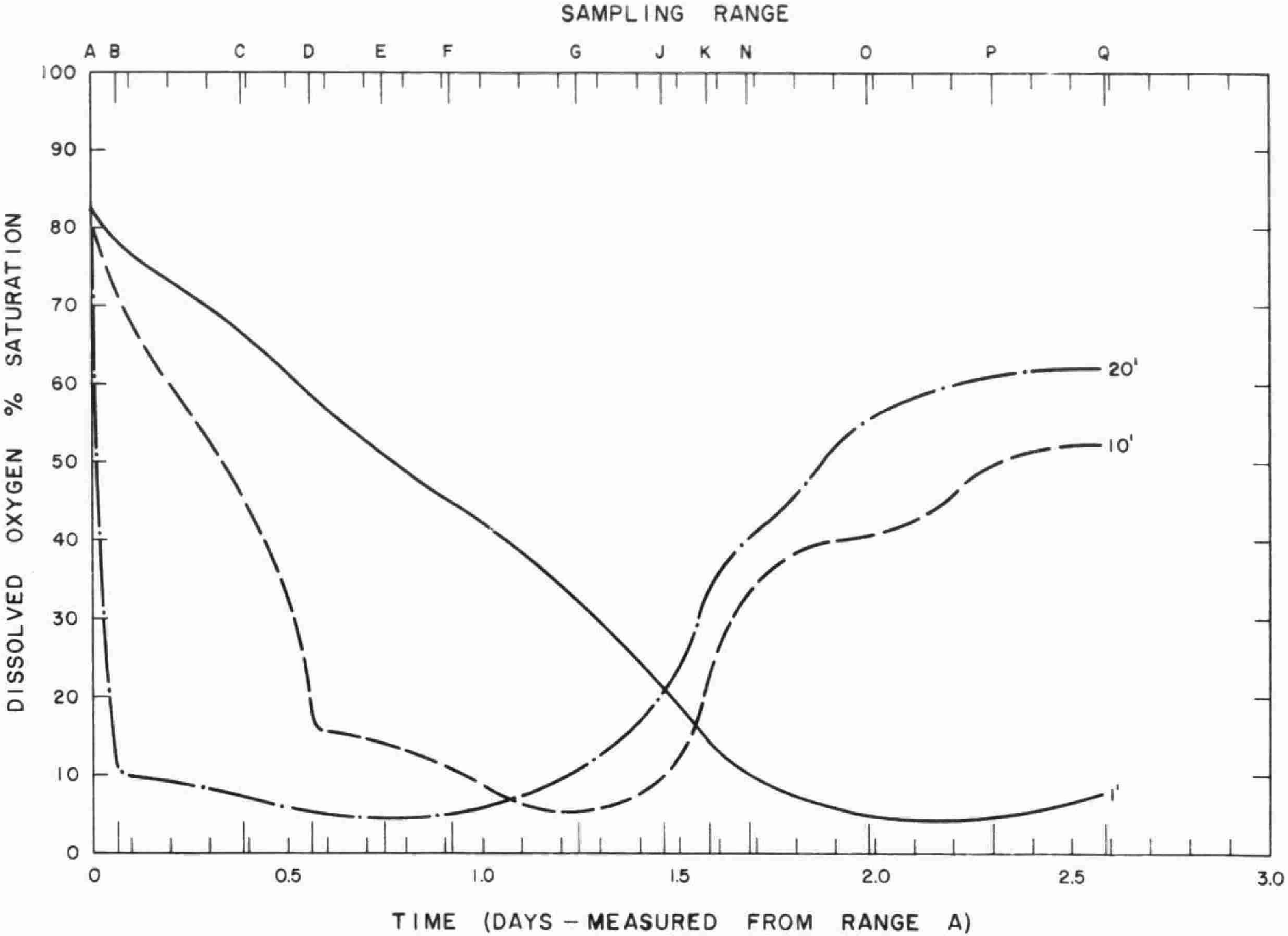


Fig. 4.3 Dissolved oxygen profiles - Zone 1

The differences between the survey and monitoring data are again likely due to low streamflow conditions at the time of the survey and the resultant low dilution of waste inputs.

Suspended solids from The Great Lakes Paper Company Limited (83 tons per day) cannot be readily detected in the Kaministikwia River even directly downstream from the mill outfalls (see Figure 4.4). This mill's coloured wastes, composed of fiberous materials (0.25 percent solids) are only a small factor in accounting for the stream's brownish, turbid appearance throughout the Turning Basin since the colour of the river upstream is similar. This discolouration, however, became less apparent downstream from the Turning Basin. Generally, suspended solids levels were lower during the August 1970 survey than the average levels measured over the past four years.

Nutrient Materials

Nutrient levels were generally low throughout the lower section of the Kaministikwia River (see Figure 4.5). Total nitrogen concentrations ranged from 0.37 mg/l upstream from the major sources of pollution to about 0.7 mg/l measured downstream from The Great Lakes Paper Company Limited and Industrial Grain Products Limited. A slight increase was also noted downstream from the outfall of the Thunder Bay South Sewage Treatment Plant.

The total phosphorus concentration averaged less than 0.04 mg/l upstream from The Great Lakes Paper Company Limited and rose slightly to 0.05 mg/l downstream from the mill outfalls. The largest increase was noted downstream from Industrial Grain Products Limited where the level averaged 0.15 mg/l. Although The Great Lakes Paper Company Limited discharged 363 lbs per day during the survey and Industrial Grain Products Limited only 88.5 pounds per day, the apparent discrepancy in the increase in the phosphorus concentration downstream from the latter was probably due to a non-representative sample which was collected before the effluent had time to mix with the river.

The average nutrient levels in the Kaministikwia River determined since 1967 do not differ significantly from concentrations measured during the 1970 water quality survey. Total nitrogen (as N) varied from 0.5 to 0.7 mg/l while total phosphorus (as P) ranged between 0.05 and 0.15 mg/l.

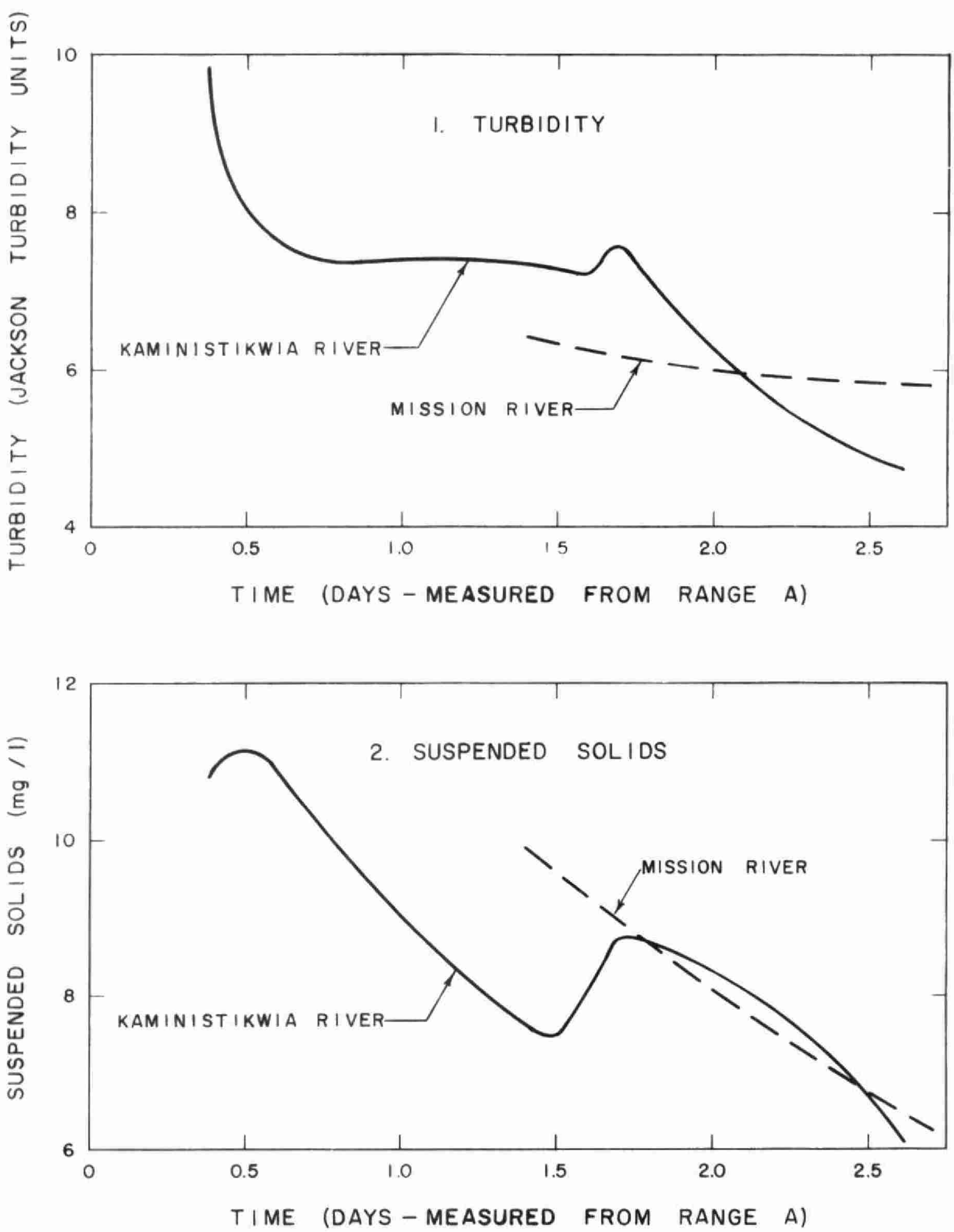


Fig. 4.4 Suspended solids and turbidity - Zone 1

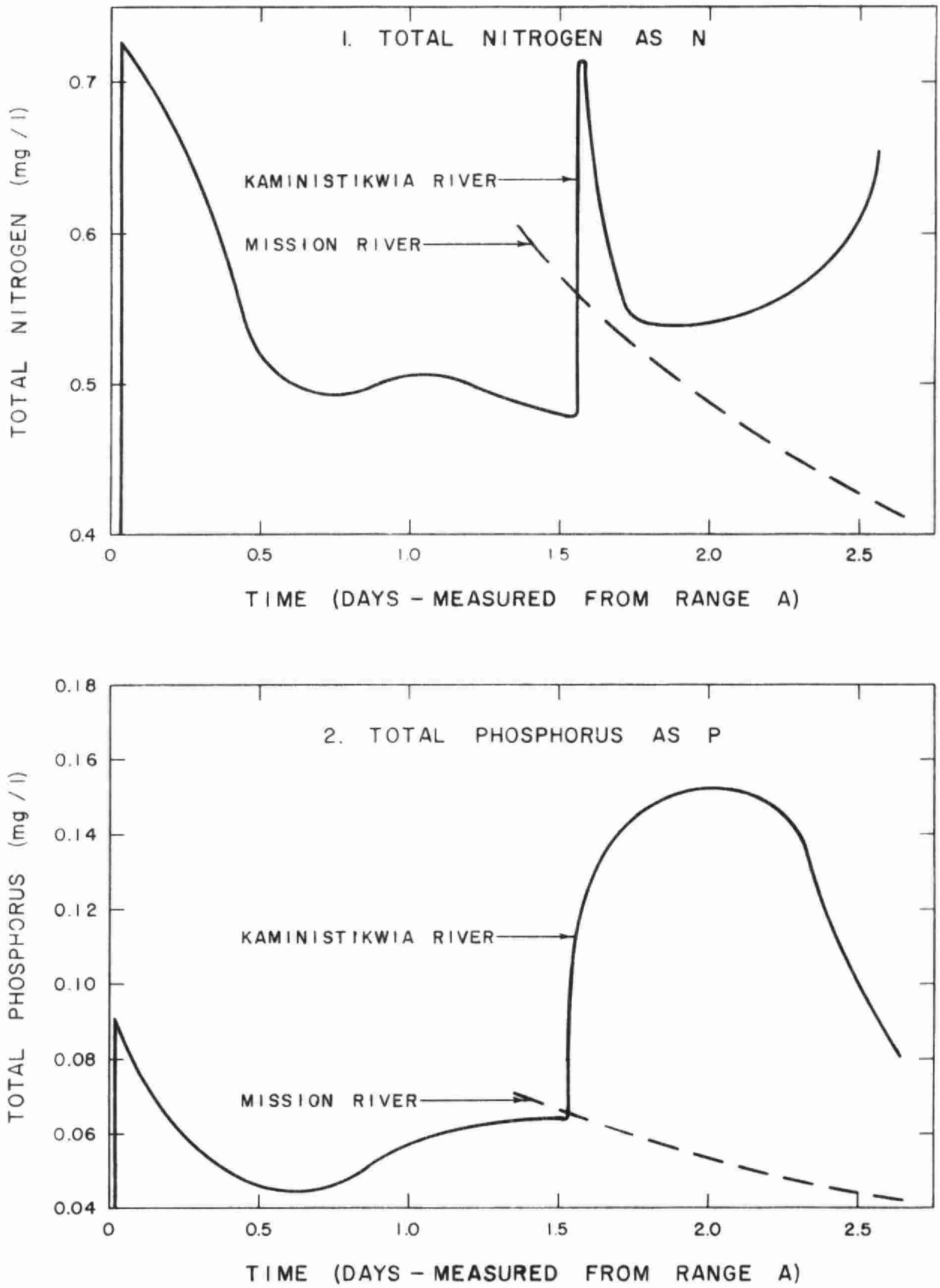


Fig. 4.5 Nutrient concentrations - Zone 1

Although significant problems due to nutrient enrichment have not been observed to date, possibly because of the toxicity of the industrial wastes particularly in the Kaministikwia River, the discharge of nutrient materials should be closely controlled to prevent future problems.

Phenolic Substances

During the August 1970 survey, the concentration of phenolic substances, which contribute to taste and odour problems in water and which are believed to partly contribute to tainting of fish flesh, were negligible in the Kaministikwia River upstream from The Great Lakes Paper Company Limited outfall. However, the average phenolic substance concentrations ranged from 9 to 14 µg/l in the downstream reaches of the river as well as at the mouth of the three channels.

The monitoring data indicated average phenolic substances concentrations of 7-8 µg/l upstream from the Great Lakes Paper Company Limited, while the downstream levels have averaged 24 µg/l.

Patches of oily wastes were observed on the surface of the Kaministikwia River downstream from the Turning Basin to the bay. Largest accumulations were found along the northwest bank of the Kaministikwia Channel adjacent to the CPR yards. These are likely attributable to fuelling operations carried out at the railway yards, however, steps are currently being taken to alleviate this problem.

Bacterial Contamination

The bacteriological criteria used by the Ministry of the Environment for assessing the acceptability of surface waters for specific uses are taken from the OWRC publication "Guidelines and Criteria for Water Quality Management in Ontario". In this publication the criteria for raw water supplies and for swimming and bathing areas are expressed as geometric means based upon at least four samples per month (one sample for each week of the month) and upon at least ten samples per month (including samples collected during weekend periods), respectively. For a raw water supply, the geometric mean levels considered permissible are 5,000 coliform organisms per 100 ml, 500 fecal coliform organisms per 100 ml and 50 fecal streptococci organisms per 100 ml. For swimming and bathing, the geometric mean levels considered permissible are 1,000 coliform organisms per 100 ml, 100 fecal coliform organisms per 100 ml, and 20 enterococcus (fecal streptococci) organisms per 100 ml. These levels are presented for comparison with the data

collected during the survey. When making comparisons, it must be acknowledged that during the period of survey, it was not possible to collect sufficient bacteriological samples to meet the geometric mean requirements of the above criteria. However, the comparisons with the criteria in this section as well as in subsequent sections provide an indication of the relative magnitude of bacteriological water quality problems.

During the August 1970 survey, bacteriological samples were collected from seven sampling ranges in the Kaministikwia River and all outfalls discharging to the river. Analytical results are summarized in Table 4.9. All bacterial values in the table as well as in the following section are expressed as geometric mean densities (unless otherwise specified).

The bacterial densities in Zone 1 were the lowest upstream from the Westfort Turning Basin (total coliform - 1,000, fecal coliform - 150, and fecal streptococcus - 79 organisms per 100 ml). Significantly higher levels were found near the outlet of the Turning Basin downstream from the outfalls of The Great Lakes Paper Company Limited and sanitary storm sewers. The highest mean densities (total coliform - 58,000, fecal coliform - 12,500, and fecal streptococcus - 11,500 organisms per 100 ml) were found in the Kaministikwia River near its junction with the McKellar River downstream from several municipal sewers and the outfall of Industrial Grain Products Limited. No significant increases, however, were noted downstream from the municipal sewage treatment plant outfall due to the chlorination of the effluent.

Bacterial levels measured during the August 1970 study were significantly higher than those measured on routine monitoring runs during the same year. For example, the median total coliform count based on the 1970 monitoring data for the Kaministikwia Channel near its junction with the McKellar Channel was 19,000 organisms per 100 ml (versus 58,000 during August). The higher bacterial densities during the survey were likely due to low streamflow conditions which resulted in relatively low dilution of wastes.

Total coliform densities for the Kaministikwia River and eleven sewer outfalls sampled during the survey are shown in Figure 4.6. The total coliform densities in these outfalls ranged from approximately 40,000 organisms per 100 ml to 250,000 organisms per 100 ml.

The bacteriological data therefore suggest that the entire Zone 1 failed to meet the accepted microbiological criteria for swimming and bathing.

TABLE 4.9 SUMMARY OF BACTERIOLOGICAL DATA, ZONE 1 - LOWER KAMINISTIKWIA RIVER

Range	Total Coliforms	Fecal Coliforms	Fecal Streptococci
	per 100 ml		
A	1,000	150	79
C	35,000	2,850	750
D	29,000	2,350	620
E	29,000 *	2,400 *	520 *
F	29,000	2,450	450
G	25,500	3,750	530
H	28,000	4,900	1,000
I	22,500 *	3,000 *	235 *
J	36,000	4,600	590
K	58,000	12,500	11,500
L	41,000	9,200	8,800
M	17,500 *	2,950 *	2,050 *
N	49,000	7,400	5,700
O	39,500 *	7,000 *	7,000 *
P	32,500	6,400	8,300
Q	31,500 *	6,600 *	2,200 *

* approximate

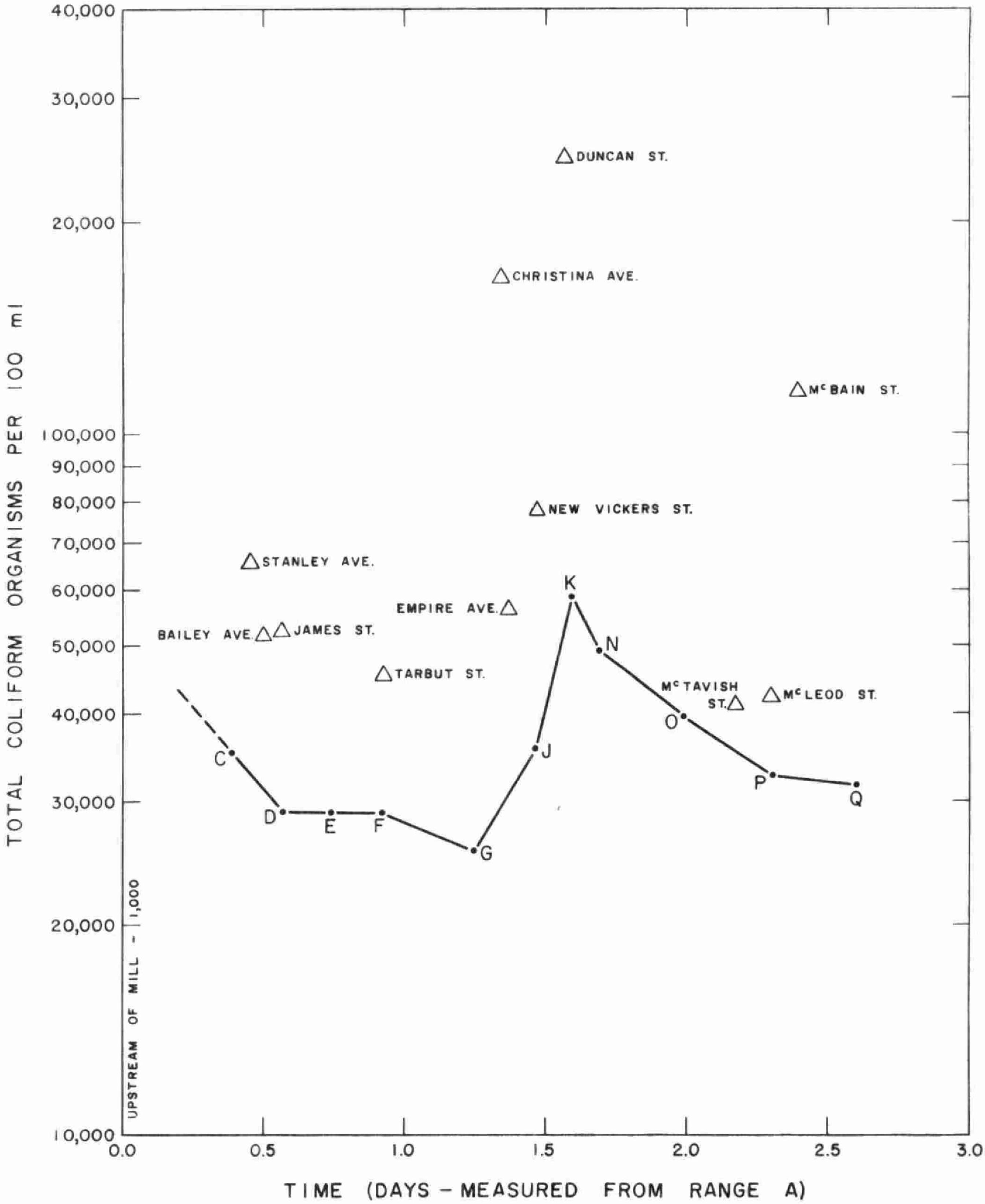


Fig. 4.6 Total coliform bacteria - Zone 1

Aquatic Life

Although the biological condition of the Kaministikwia River was not examined during this survey, earlier studies (OWRC 1969) indicated that the aquatic life throughout most of the lower river had been impaired. The impairment was attributed to accumulations of sludge which produced unsuitable substrate for normal macroinvertebrate habitation. In addition, low dissolved oxygen levels accompanied by elevated water temperatures have restricted the variety of fish to only the coarser species and have caused fish kills over the past few years.

Sediments

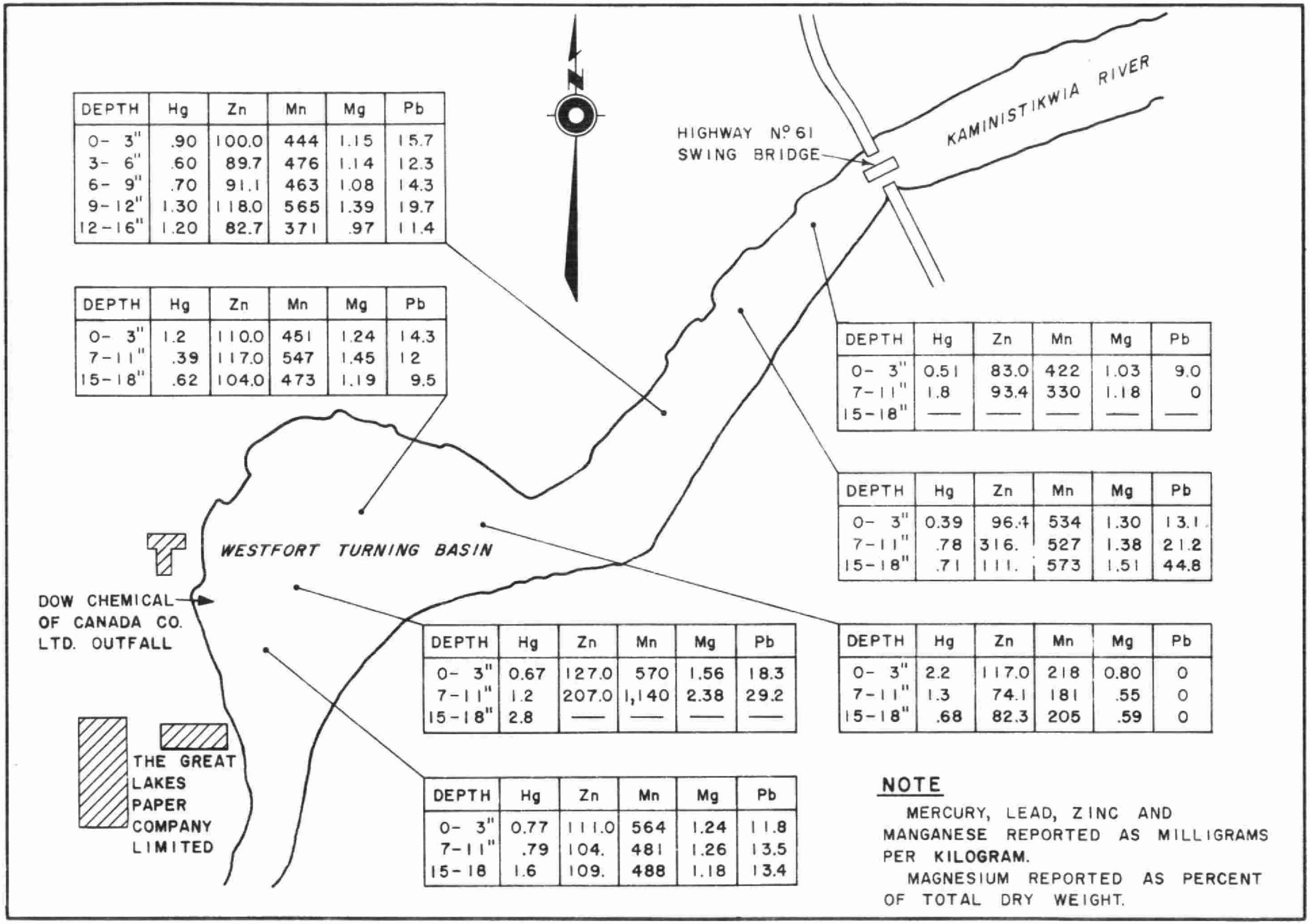
Accumulations of decomposing bottom deposits were found downstream from The Great Lakes Paper Company Limited outfalls, throughout the Turning Basin and for about 1 1/2 miles downstream from the basin. These odiferous, black, near-gelatinous deposits were composed primarily of clay, silt, wood fibre and some wood chips, and in the Turning Basin, contained up to 85 percent volatile material (average 30 to 40 percent). Downstream from the Turning Basin and at the mouths of the three channels, the sediments contained less than 10 percent volatiles.

The oxygen uptake rate of the bottom deposits taken directly downstream from the Turning Basin was approximately 0.33 grams per square meter per day. This rate is relatively low compared to the 3 - 5 $gm/M^2/day$ rate usually found downstream from pulp and paper mills. This is probably due, in part, to the low level of dissolved oxygen in the overlying water. Large amounts of gas escaping from the streambed indicated active anaerobic decomposition of the solid deposits.

The metal analyses for sediment samples collected in and directly downstream from the Westfort Turning Basin, included determinations of mercury, manganese, zinc, magnesium and lead. Samples in the lower reaches were analyzed for mercury only to examine the extent of contamination by mercurial compounds from the chlor-alkali plant owned and operated by the Dow Chemical Company. The analytical results are presented in Figure 4.7.

Mercury levels ranged from 0.07 mg/kg at the new Highway #61 Bridge (not shown in Figure 4.7) located about 3/4 mile upstream from the Westfort Turning Basin, up to 12.8 mg/kg near the outlet of the Turning Basin.

Immediately adjacent to the outfall of the Dow Chemical of Canada Limited, in the Turning Basin, concentrations of mercury as high as 11.1 mg/kg were measured. At the mouths of the



DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	.90	100.0	444	1.15	15.7
3- 6"	.60	89.7	476	1.14	12.3
6- 9"	.70	91.1	463	1.08	14.3
9-12"	1.30	118.0	565	1.39	19.7
12-16"	1.20	82.7	371	.97	11.4

DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	1.2	110.0	451	1.24	14.3
7-11"	.39	117.0	547	1.45	12
15-18"	.62	104.0	473	1.19	9.5

DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	0.51	83.0	422	1.03	9.0
7-11"	1.8	93.4	330	1.18	0
15-18"	—	—	—	—	—

DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	0.39	96.4	534	1.30	13.1
7-11"	.78	316.	527	1.38	21.2
15-18"	.71	111.	573	1.51	44.8

DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	0.67	127.0	570	1.56	18.3
7-11"	1.2	207.0	1,140	2.38	29.2
15-18"	2.8	—	—	—	—

DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	2.2	117.0	218	0.80	0
7-11"	1.3	74.1	181	.55	0
15-18"	.68	82.3	205	.59	0

DEPTH	Hg	Zn	Mn	Mg	Pb
0- 3"	0.77	111.0	564	1.24	11.8
7-11"	.79	104.	481	1.26	13.5
15-18	1.6	109.	488	1.18	13.4

NOTE

MERCURY, LEAD, ZINC AND MANGANESE REPORTED AS MILLIGRAMS PER KILOGRAM.

MAGNESIUM REPORTED AS PERCENT OF TOTAL DRY WEIGHT.

Fig. 4.7 Metals in sediment samples

Kaministikwia, McKellar and Mission rivers, mercury levels were 1.8, 0.9 and 1.8 mg/kg, respectively.

Concentrations of zinc in the Kaministikwia River ranged from a maximum of 316 mg/kg, 2,000 feet downstream from the Turning Basin to a minimum of 74.1 mg/kg near the outlet of the basin.

Lead in the sediments ranged from 44.8 mg/kg about 2,000 feet downstream from the Turning Basin to 0.0 mg/kg near the outlet of the basin.

Manganese and magnesium levels ranged from 1,140 mg/kg and 23,800 mg/kg (total dry weight respectively), in the south centre of the Turning Basin to 181 mg/kg of manganese and 5,500 mg/kg magnesium near the outlet of the basin.

4.2.2. Zone 2 - Thunder Bay Inner Harbour

The water quality of Thunder Bay Inner Harbour has been impaired by industrial and municipal wastewater discharges. The most significant impairment has occurred in the north and south sections of the harbour which receive the major waste inputs. Details on the water quality conditions are discussed in the sections which follow. Analytical data for Zone 2 are presented in Appendix B.

Biochemical Oxygen Demand - Dissolved Oxygen Variation

Figure 4.8 shows levels of dissolved oxygen expressed as percent saturation for Thunder Bay Inner Harbour as measured during the August 1970 survey. Although significant loadings of BOD_5 were discharged to this area, no serious effects on dissolved oxygen levels were observed. The percent saturation values in the Inner Harbour were generally found to be inversely proportional to the distance from waste sources. The minimum dissolved oxygen (5.4 mg/l) was encountered in the north section of the harbour which is influenced mainly by the waste input from the Abitibi Provincial Paper, A Division of Abitibi Forest Products Limited. This level of dissolved oxygen approaches the minimum accepted criteria for warm water fisheries of 5.0 mg/l.

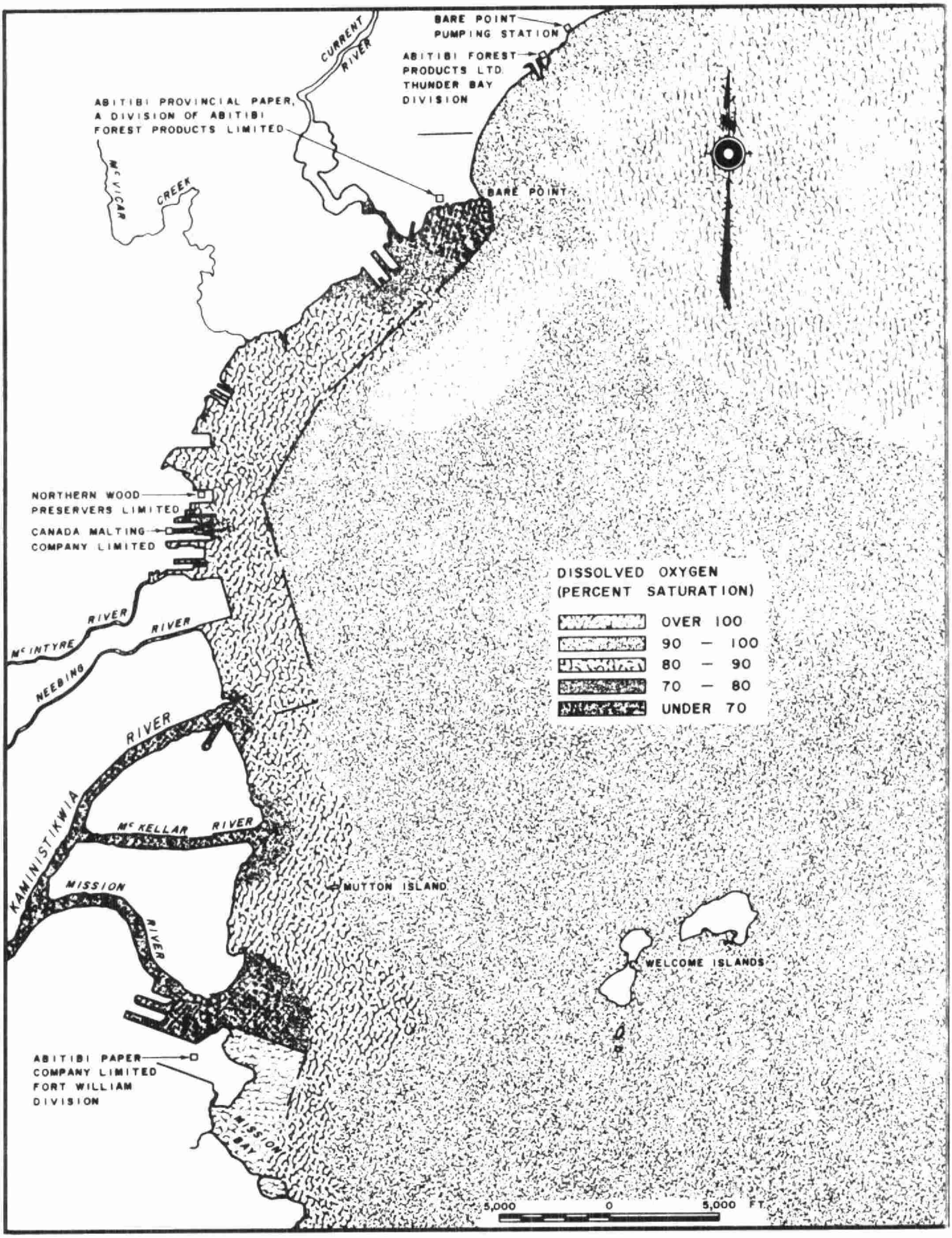


Fig. 4.8 Dissolved oxygen levels - Zones 2 and 3

Elsewhere in the Inner Harbour the dissolved oxygen level ranged from 80 to 90 (6.1 to 10.0 mg/l) percent saturation except in a small area adjacent to the Canada Malting Company where the levels were less than 70 percent saturation (5.8 to 6.7 mg/l). Although it appears from these findings that the BOD_5 input into the harbour area is not adversely affecting its water quality, the continuing discharge of carbonaceous materials may contribute to water quality deterioration on a long-term basis. Consideration should therefore be given to reducing discharges of materials to lessen the risk of build-up of carbonaceous materials which, on a long-term basis, could lead to the water quality deterioration of Lake Superior.

Nutrient Materials

Nutrient levels, particularly total phosphorus, were significantly higher in the north and south sections of the harbour. Figures 4.9 and 4.10 show total phosphorus and total nitrogen concentrations, respectively, in the area. The maximum value of total phosphorus encountered in the harbour was 0.12 mg/l which occurred at a point opposite the Clarke Street sewer. Generally, the levels of total phosphorus in the harbour were found to average about five times higher than levels in the outer harbour, with many areas exhibiting total phosphorus concentrations of between 0.03 and 0.04 mg/l.

Phenolic Substances

The highest concentrations of phenolic substances were encountered in the north part of the Inner Harbour which is influenced by the waste inputs from the Abitibi Provincial Paper, A Division of Abitibi Forest Products Ltd. The average levels in the area of the harbour extending north from the mouth of the Current River ranged from 19 μg/l to 28 μg/l (Station 134, 135 and 518). Southwards from the mouth of Current River to approximately half-way between McVicar Creek and the Current River, phenolics ranged from 5.8 to 12.4 μg/l (Stations 132, 519 and 138). Elsewhere in the Inner Harbour average levels ranged from 1 to 3.4 μg/l.

Bacterial Contamination

The bacterial contamination followed a pattern similar to that of general water quality degradation viz. the north and

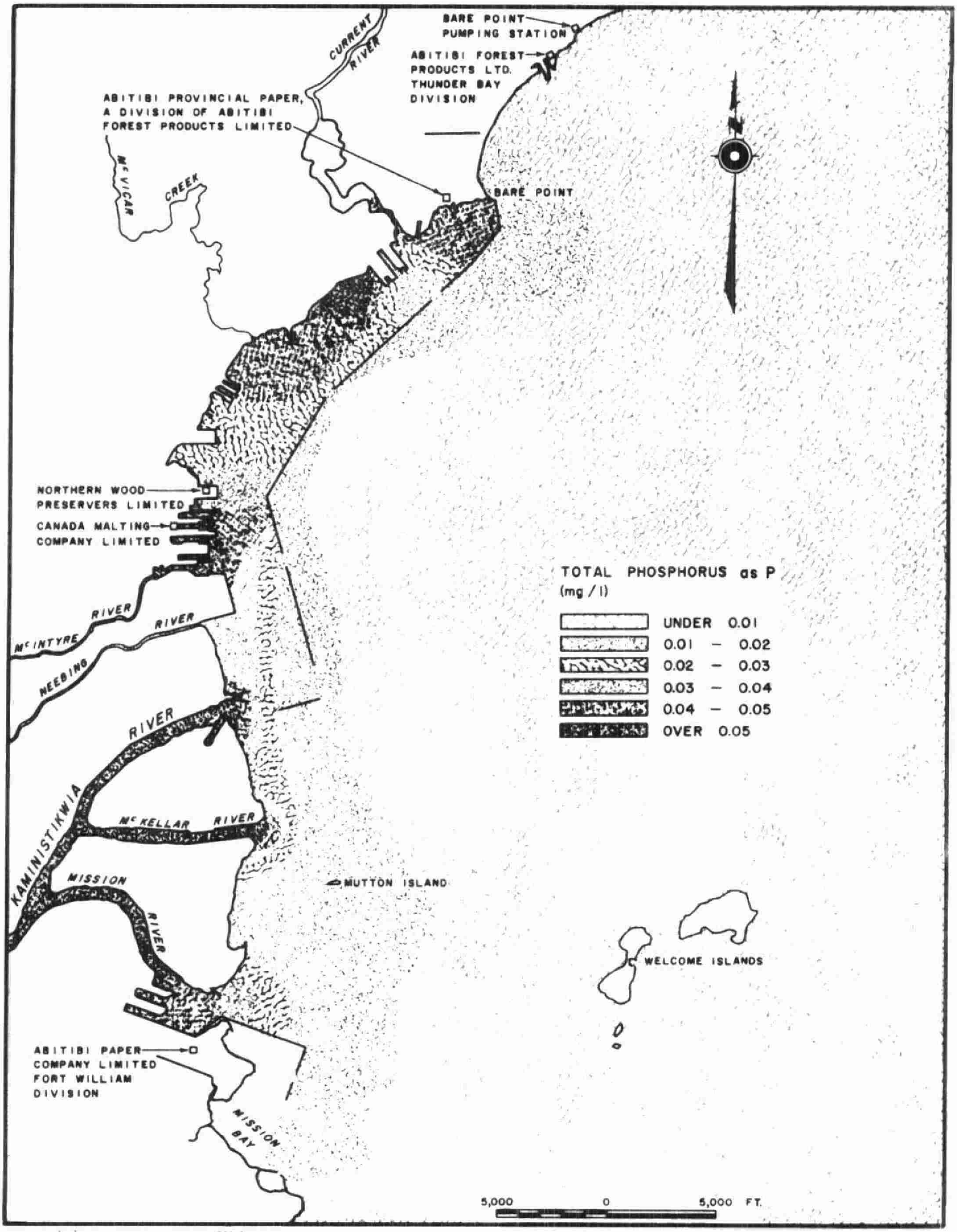


Fig. 4.9 Total phosphorus - Zones 2 and 3

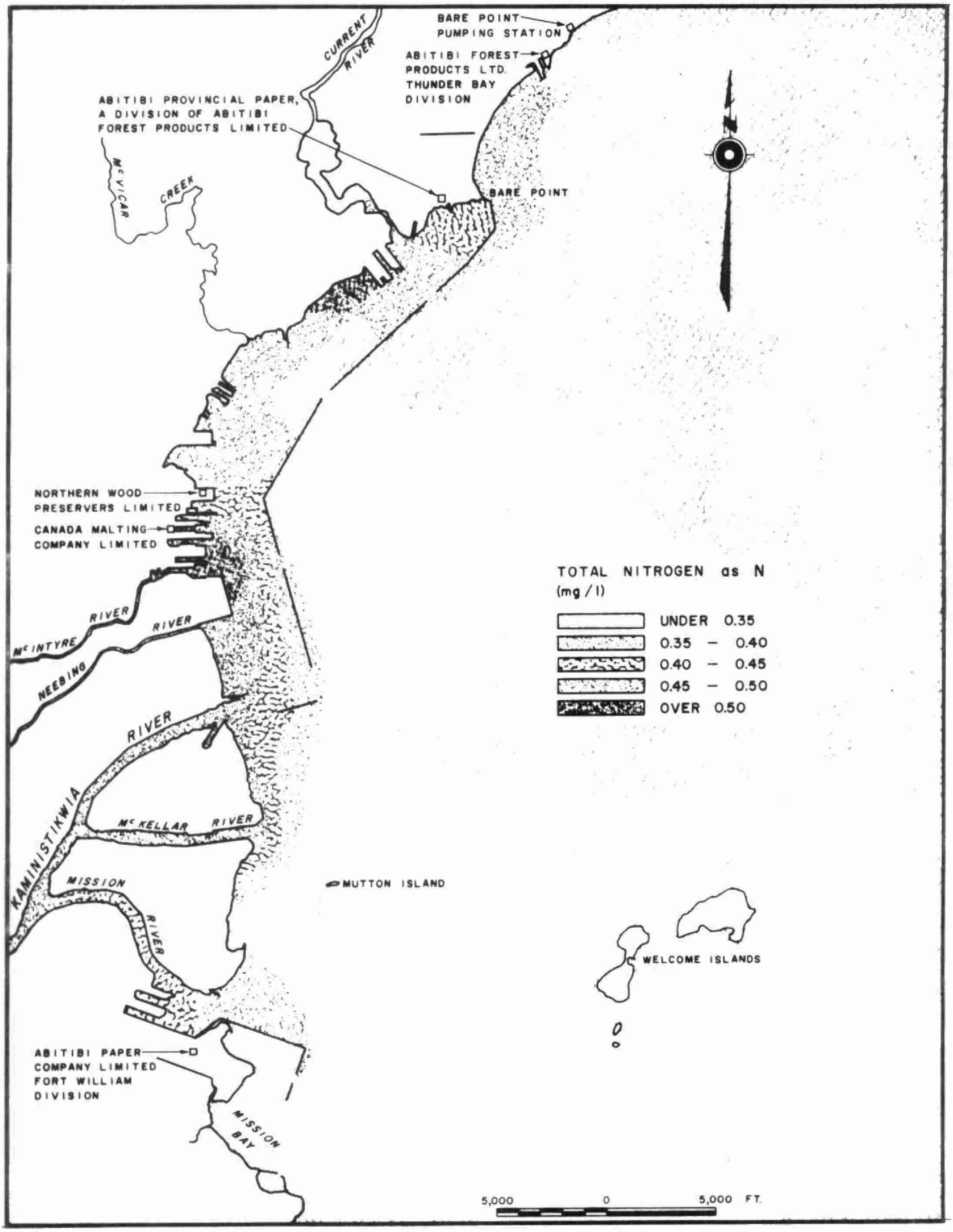


Fig. 4.10 Total nitrogen - Zones 2 and 3

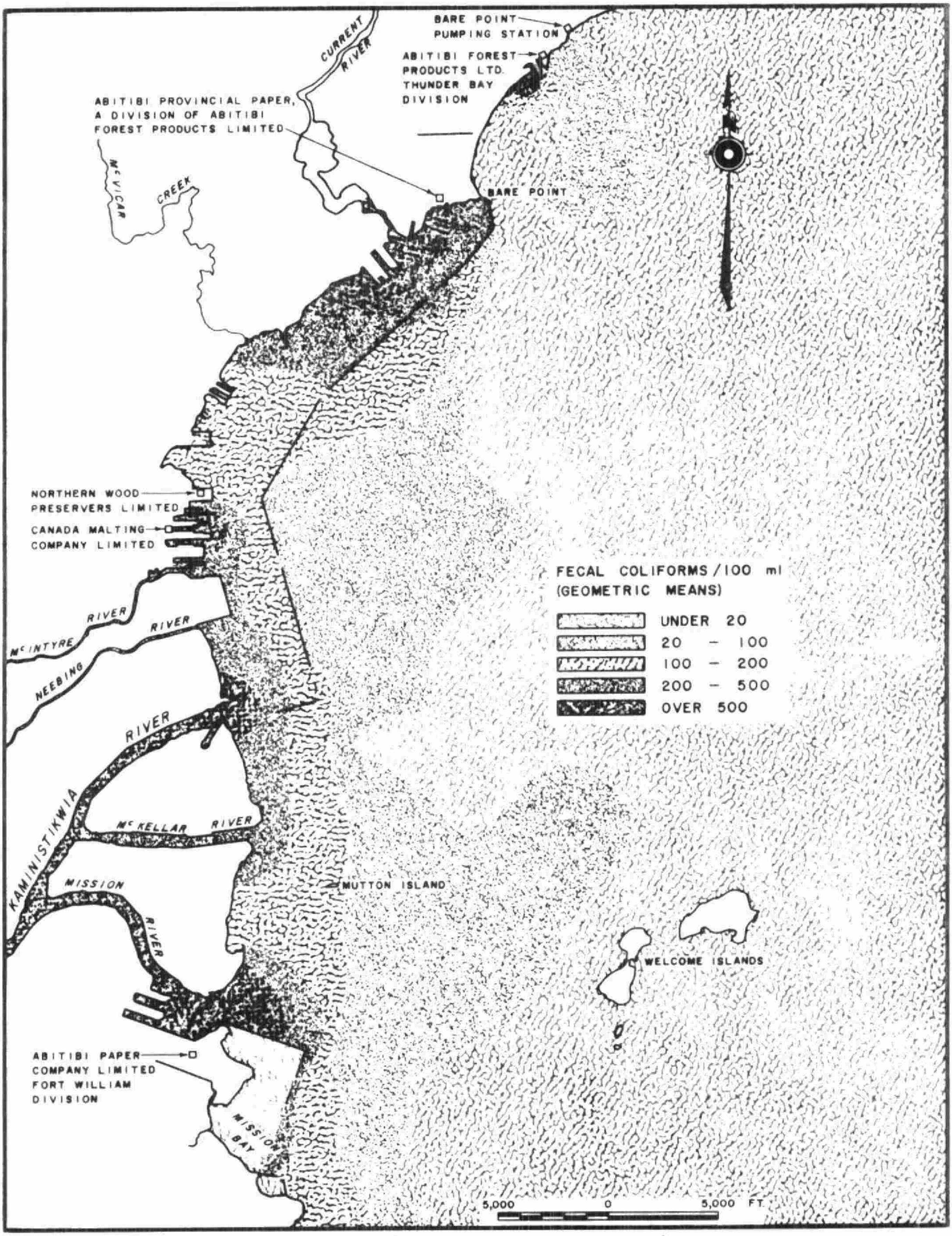


Fig. 4.11 Fecal coliforms - Zones 2 and 3

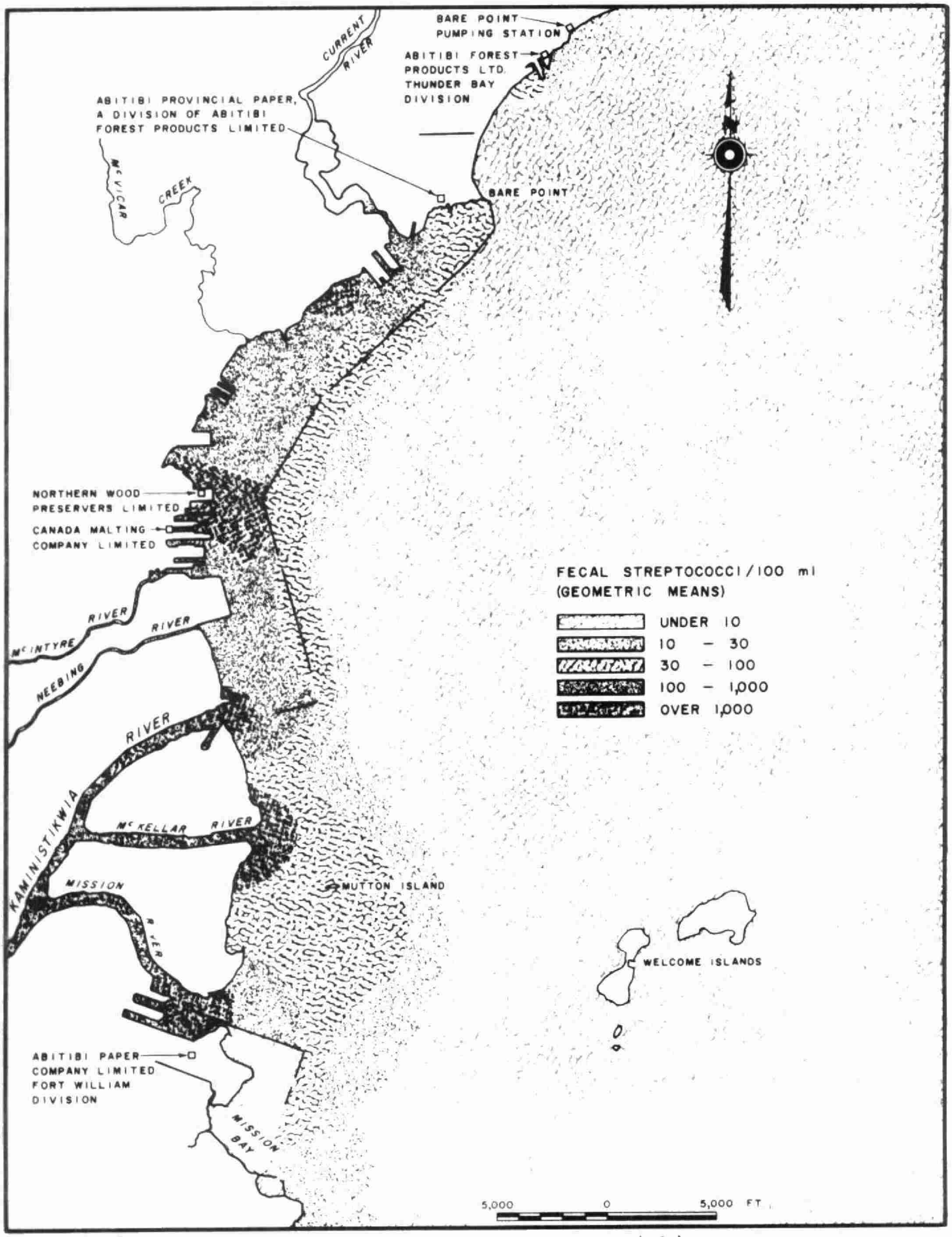


Fig. 4.12 Fecal streptococci - Zones 2 and 3

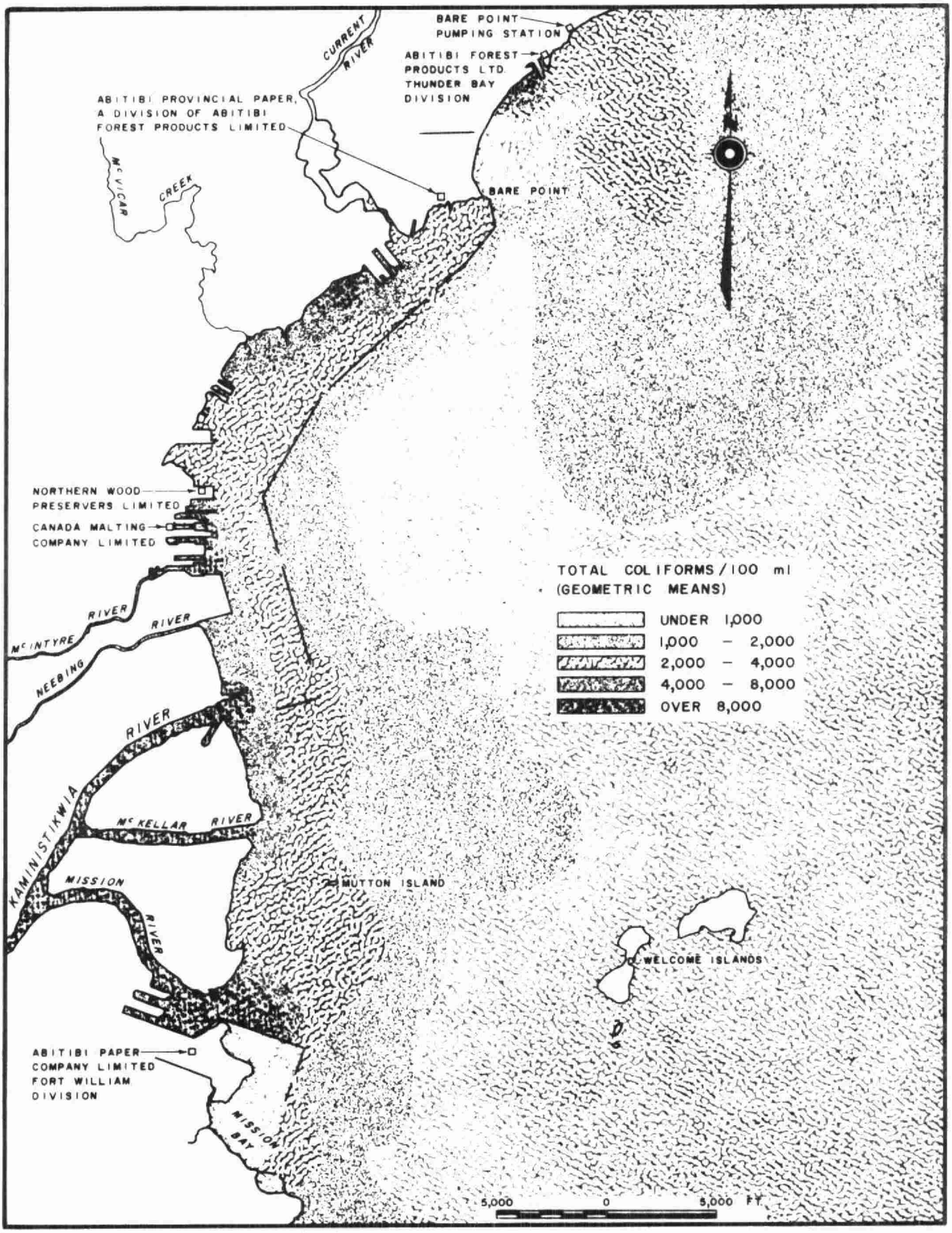


Fig. 4.13   Total coliforms - Zones 2 and 3

south portions of the Inner Harbour were more seriously affected than the central section.

In all sections of the harbour, the accepted criteria for swimming and bathing of 1,000, 100 and 20 organisms per 100 ml for total coliform, fecal coliform and fecal streptococcus, respectively were exceeded (see Figures 4.11, 4.12 and 4.13).

The highest densities for total coliform, fecal coliform and fecal streptococcal organisms were found in the vicinities of the Clarke Street sewer outfall, The Canada Malting Company Limited slip, and the outfall of the mill of Abitibi Provincial Paper, A Division of Abitibi Forest Products Limited. In these areas, the geometric mean values of fecal streptococcal bacteria exceeded 100 organisms per 100 ml. The highest count of 10,000 organisms per 100 ml was found near the Canada Malting Company Limited outfall.

Significant bacterial contamination was also found near the mouths of McVicar Creek and the McIntyre and Neebing rivers.

4.2.3 Zone 3 - Thunder Bay Outer Harbour

The area of Thunder Bay Outer Harbour adjacent to the Inner Harbour can be divided into four distinct regions with respect to waste inputs and resulting water quality. The first region, in the north section of Zone 3, is the area opposite the outfalls from Abitibi Forest Products Limited, Thunder Bay Division mill and the Lillian Street combined sewer. The water quality in this area, especially close to the mill outfall, is significantly impaired with respect to BOD , COD, solids and bacteria. However, since at the time of the survey these outfalls were close together, it is difficult to differentiate the sources of contaminants. The second region opposite the harbour breakwall, showed little degradation mainly because the small openings in the harbour breakwall at this point restrict water from flowing into the Outer Harbour and affecting its quality. The third region is opposite the mouths of the Kaministikwia, McKellar and Mission rivers. It is impaired also with respect to BOD, COD, solids and bacteria. Water flow (outwards from the Inner Harbour) was estimated to be 582 cfs in 1970 (based on annual average). This flow is composed of the flows for the McIntyre, McVicar and Current rivers plus the measured flows of the Neebing River and the effluent mill of the Abitibi Provincial Paper, A Division of Abitibi Forest Products Limited. Since the three northerly openings in the harbour breakwall are

small, it was assumed that the flow outwards from the south end of the inner harbour was equal to the flow of the Kaministikwia River water into the harbour. However, current studies should be conducted to define this more clearly. Thus, the Kaministikwia River flow moves eastward through the south entrance of the inner harbour and out into the outer harbour with minimum impingement on inner harbour water quality. The river loads outlined in Table 4.8, adversely affected water quality in the immediate receiving area.

The fourth region in Zone 3 is that area opposite the Abitibi Paper Co. Ltd., Fort William Division mill. Although the waste load is discharged inside the breakwall, there is an adverse effect on water quality outside the breakwall due to current action. It would be desirable to examine the current distribution in the area to define this more closely.

Analytical data for Zone 3 are presented in Appendix B.

Bacterial Contamination

Bacterial levels measured in Zone 3 are shown on Figures 4.11, 4.12 and 4.13. The area of the bay immediately northeast of Bare Point was less seriously affected than the rest of Zone 3. Fecal streptococcal and fecal coliform densities were less than 10 and 20 organisms per 100 ml respectively in this area. Elsewhere in Zone 3 bacterial contamination was more serious, indicating that water quality impairment extended beyond the breakwall. For example, both fecal and streptococc counts in Thunder Bay immediately adjacent to the breakwall ranged between 20 and 100 organisms per 100 ml, while the total coliform counts exceeded 2,000 organisms per 100 ml. In the vicinity of the outfall from the mill of Abitibi Forest Products Ltd., Thunder Bay Division and the Lillian Street combined sewers, the fecal coliform and fecal streptococcal counts ranged from 20 to over 500 and 10 to 100 organisms per 100 ml respectively.

Near the mouths of the Kaministikwia and Mission rivers, fecal steptococcal counts exceeded 100 organisms per 100 ml. The highest streptococcus count (7,500 organisms/100 ml) was found at the mouth of the Mission River.

In general, total coliform, fecal coliform and fecal streptococcal levels in Zone 3, with the exception of the area immediately northeast of Bare Point, exceeded accepted criteria for public surface water supply (OWRC, 1970). Although the bacterial water quality in the vicinity of the Bare Point pumping station during this survey was within the criteria for a public water supply, it is conceivable that the water quality in this area could be contaminated further under different weather and current conditions. This has been borne out by recent problems of bacteria gaining access to the water supply distribution system. There has also been a taste

problem probably due to chemical and biological factors. It would be desirable to conduct further surveys including the current study patterns and biological investigations to define this problem more closely.

Biochemical Oxygen Demand and Dissolved Oxygen

The dissolved oxygen levels in the receiving areas of the McKellar and Mission rivers were less than 70 percent saturation while concentrations near the mouth of the Kaministikwia River were between 70 percent and 80 percent saturation. The overall dissolved oxygen percent saturation of the bay itself was 99 percent.

These trends are shown on Figure 4.8.

In this area dissolved oxygen levels were not depressed significantly by the organic wastewater (BOD_5) input. However, the BOD5 loadings should be reduced to lower the risk of build-up of carbonaceous material on a long-term basis.

Nutrient Materials

The total phosphorus and total nitrogen levels measured during this survey are depicted in Figures 4.9 and 4.10 respectively. As shown in Figure 4.9 the total phosphorus levels at the mouths of the three rivers were over 0.05 mg/l. The levels varied inversely with increasing distances outwards into the bay. In the vicinity of the Abitibi Forest Products Ltd., Thunder Bay Division mill, the phosphorus levels were similar to background levels of the outer bay.

Total nitrogen levels near the mouths of the Kaministikwia and McKellar rivers were above 0.45 mg/l while the level near the mouth of the Mission River was 0.40 mg/l. As with phosphorus, the nitrogen levels decreased with increasing distance into the bay. At the three river mouths total phosphorus levels in several instances exceeded 0.05 mg/l but generally ranged from 0.04 to 0.05 mg/l. These levels also decreased with increasing distance into the bay. The area opposite the breakwall and near the Abitibi Forest Products Ltd., Thunder Bay Division and Lillian Street combined sewer showed only a slight variation from the background nutrient concentrations of the outer bay.

Phenolic Substances

The concentrations of phenolic substances in Zone 3

were highest in the vicinities of the paper mill outfalls, the Lilliam Street sewer and near the mouths of the Kaministikwia River channels. In general, the levels decreased with increasing distance from the sources. For example, near the mill of the Abitibi Paper Company Ltd., Fort William Division, the level ranged from an average of about 9 μg/l near the breakwall to an average of 5 μg/l at a distance of ½ mile from the breakwall. Farther out in the bay, the levels decreased to a range of 1-3 μg/l. At about ½ mile from the mouths of the channels the average levels ranged from 3.2 to 8.4 μg/l. The levels decreased with increasing distance into the bay but still remained at approximately 1.5 μg/l at a distance of 3 miles from shore. Near the vicinity of the mill of the Abitibi Forest Products Ltd., Thunder Bay Division, and the Lillian Street sewer, the average concentration of phenolic substances ranged from 3.0 to 7.2 μg/l, while further offshore, levels decreased to a range of between 1 to 2 μg/l.

Thermal Inputs

Ontario Hydro's Thunder Bay Generating Station utilized approximately 75 MIGD of cooling water during 1970. A summary of the temperature rise of this cooling water as well as average 1970 load generation (KWH) is given in Table 4.12. The average temperature rise was 5.9 F above ambient with a range of 2.1 to 10.9°F; however, it should be noted that the station only used 32 percent of its maximum generating capacity. Currently, there is only a low thermal effect on adjacent Thunder Bay as a result of the discharge of cooling water. No other impairment of water quality can be attributed to the HEPCO plant at this time. Once the plant is operated at full capacity it would be desirable to re-examine the effects of the heated discharges.

CHAPTER 5

WATER QUALITY CONTROL

5. WATER QUALITY CONTROL

The primary objective of sound water quality management is to provide water suitable for a variety of uses including public, agricultural and industrial supply, recreation, aesthetic enjoyment and propagation of fish and wildlife. The utilization of waters for assimilation and dilution of wastes must take these uses into consideration. Wherever possible, attempts should be made to upgrade water quality to ensure satisfactory supplies for future demands exerted by increasing population and industrial growth, urbanization and technological change.

Because of its importance as the largest Canadian city on the shores of Lake Superior and its position as the western terminus for the Seaway system, Thunder Bay possesses great potential for future growth and development. Since a clean aquatic environment with a good supply of water and adequate facilities for waste disposal are important criteria in planning for municipal and industrial growth, every practicable effort should be made to alleviate the existing water pollution problems in the Thunder Bay area (discussed in Chapter 4). Restoration of satisfactory water quality would not only provide a wider range of water uses for the enjoyment of the existing population, but would also attract new development to the area.

Implementation of the pollution abatement programs presently proposed by the City of Thunder Bay and the major industries in the area will result in significant improvements in water quality. The most notable changes are expected to occur in the Kaministikwia River where bacteriological pollution from the municipal waste sources and the suspended solids problem from the industrial sources will be greatly alleviated upon completion of these programs. This latter problem has already been greatly alleviated since the August 1970 survey.

The water quality impairment in Thunder Bay Harbour and the adjoining area of Thunder Bay could not be attributed to discharges of oxygen-consuming wastes and nutrient materials at the time of this study. However, the continuing discharge of carbonaceous and other nutrient materials from both industrial and municipal sources may lead to build-up of these substances which could result in water quality impairment on a long-term basis. The discharges should therefore be controlled to the highest degree practicable to avoid the risk of build-up of carbonaceous and other nutrient materials for long-term protection of the waters in the area.

As discussed in Chapter 4, it is recognized that even after implementation of the present proposals, the dissolved oxygen criterion of 5 mg/l necessary for the protection of fish in the Kaministikwia River may not be achieved during low streamflow conditions because of the limitations in the degree of removal of oxygen-consuming wastes from pulp and paper mill effluents through existing waste treatment technology. However, with further advances in technology and continuation of pollution control programs by the industry, it is expected that water quality can be restored to an acceptable level.

5.1 PROPOSED WATER QUALITY STANDARDS

The OWRC publication "Guidelines and Criteria for Water Quality Management in Ontario", presents water quality criteria necessary for specific water uses within the drainage basins of the province. These guidelines have been used in the preparation of these proposed standards. In this report, two sets of standards for the Thunder Bay area are proposed; one set for Zones 1 and 2 (Kaministikwia River and Thunder Bay Inner Harbour), and a second set for Zone 3 (Thunder Bay Outer Harbour). The Zone 3 standards imply considerable improvement in water quality with increasing distance from the shoreline. If these standards are met, it is believed that restoration to near background levels should occur within a reasonable distance beyond the outer periphery of Zone 3. At this time, standards for the open water of Lake Superior have not been finalized by the Canadian and United States authorities although the objectives developed by the IJC for the Lower Great Lakes may be used as the minimal basis for the Upper Lakes. It is expected, however, that a non-degradation policy with stringent water quality criteria will be used in the preparation of water quality standards for this water resource. A preliminary set of water quality criteria has also been suggested by the Lake Superior Water Quality Technical Committee. The proposed standards for Zone 3 are compatible with these criteria and are more stringent than the IJC objectives. In addition, general standards dealing mostly with aesthetics and which are applicable to the three zones are presented in sub-section B.

A) SPECIFIC STANDARDS

Parameter	i) Zones 1 and 2 [1]	ii) Zone 3
Dissolved Oxygen	5 mg/l (Mid-June to mid-September) 6 mg/l (Mid-September to mid-June) [2]	9 mg/l
Turbidity	50 Jackson Turbidity Units (Zone 1) 25 Jackson Turbidity Units (Zone 2)	5.0 Jackson Turbidity Units
Phenolic Substances	0.001 mg/l	0.001 mg/l
pH	6.5 - 8.5	6.5 - 8.5
Toxic Substances	Toxic substances must not be added concentrations or combinations that are toxic to human, animal or plant life. [3]	
Microbiological	(Membrane Filter Technique) [4]:	
Total coliform	1,000/100 ml	1,000/100 ml
Fecal coliform	100/100 ml	100/100 ml
Fecal streptococcus	20/100 ml	20/100 ml

1 *These standards apply in all waters within Zones 1 and 2 with the exception of mixing zones which will be defined by the Ministry of the Environment on an individual basis.*

2 *The dissolved oxygen level of 6.0 mg/l is required during fish spawning periods between mid September and mid June.*

3 *Refer to OWRC "Guidelines and Criteria for Water Quality Management in Ontario".*

4 *The limits are expressed as geometric means based on at least 10 samples per month.*

B) GENERAL STANDARDS

i) Tainting substances - all materials that impart odour or taste to fish or edible invertebrates shall be excluded from the water at levels determined to produce tainting.

ii) Taste - all substances that will impart an objectionable taste to the water shall be excluded from the water.

iii) Odour causing materials that are not readily removable by conventional water treatment consisting of coagulation, flocculation, sedimentation, rapid sand filtration and chlorination shall not be discharged to the waters of the study area.

iv) Oil, petrochemical or other immiscible substances that will cause visible films or toxic, noxious, or nuisance conditions shall not be discharged to the water.

v) Nutrients from unnatural sources which will stimulate the overproduction of algae, nuisance vegetation, or offensive slime growths shall not be discharged to the water.

vi) Temperature - the normal daily and seasonal temperature variations that were present before the addition of heat due to other than natural causes shall be maintained.

Heated discharges to the water will not be permitted unless it is clearly demonstrated that heated effluents will enhance the usefulness of the water resource without endangering the production and optimum maintenance of wildlife, fish and other aquatic species. It shall be the responsibility of the user to provide evidence to support the acceptability of the discharge under these terms.

Heat may not be discharged in the vicinity of spawning areas or where increased temperature might interfere with recognized movement of spawning or migrating fish populations.

vii) Settleable materials - substances shall not be added that will adversely affect the aquatic biota or will create objectionable deposits on the bottom or shore of the river.

viii) Water uses in the Thunder Bay area should be controlled to prevent the degradation of existing high quality of Lake Superior water through the significant increase in concentration of hardness, chlorides, suspended materials, turbidity and other parameters indicative of water quality degradation.

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APPENDIX A

APPENDIX A

MODELLING THE DO/BOD RELATIONSHIP IN THE KAMINISTIKWIA RIVER

A.1 MODELLING CONSIDERATION

A river can be considered as a complex system composed of interacting physical, chemical and biological forces. The overall system or any of the sub-systems making up the whole, respond to changes in waste input, hydrodynamic and physical conditions. The results of some of these changes are quite easy to predict and are readily observable. Others result in more subtle alterations to the system but these too, with proper testing techniques can be measured.

The purpose of a model, either physical or mathematical is to reproduce forces within the system, and, once verified, to predict changes in water quality conditions for any combination of alterations to the various forcing functions mentioned above.

It is obvious that a model of the several forces occurring in a watercourse provides an extremely useful tool for solving immediate pollution problems and for assisting in long-term planning of water use and development within a river basin.

In the lower Kaministikwia River, one pulp and paper mill, one food processing plant, one municipal sewage treatment plant and several uncontrolled storm and sanitary sewers discharge oxygen-consuming waste products to the river system and these materials almost completely deplete the dissolved oxygen resources of the river to its mouth. In an effort to determine the organic loading limits that should be placed on each pollution source, a mathematical model of the dissolved oxygen-biochemical oxygen demand relationship was developed.

In this Appendix, the findings of the field investigations, modelling techniques, the evaluation of model parameters, and the calculation of allowable loadings are presented.

Because this is the first attempt at a mathematical model of the Kaministikwia River, the resultant allowable waste loadings should be considered as interim guidelines approximating the BOD reduction required to maintain certain dissolved oxygen levels.

A-2 DO-BOD MODELLING

A flowing, unpolluted stream has an abundance of dissolved oxygen available for the use of the aquatic community. When unstable organic material from man-made or natural sources is introduced, biochemical oxidation utilizing the oxygen resources of the watercourse proceeds. As the organic loading is increased, greater demands are placed on the stream's oxygen supply and a point is reached where the rate of removal of dissolved oxygen (deoxygenation) is greater than the rate of atmospheric reoxygenation. When this occurs, the oxygen level in the stream begins to decrease and, in the extreme condition, can be completely depleted.

The purpose of DO/BOD modelling is to determine the level of organic loading that can be discharged to a watercourse and yet maintain a pre-determined level of dissolved oxygen.

A modified version of the Streeter-Phelps equation (Manhattan 1968) relating oxygen utilization to reaeration was employed. This equation is written as follows:

$$D = \frac{k_d . L_o}{k_2 - k_r} \left(e^{-k_r t} - e^{-k_2 t}\right) + D_o e^{-k_2 t} + \frac{S}{k_2} \left(1 - e^{-k_2 t}\right)$$

Where

D_o = dissolved oxygen deficit (pounds per day) at the point of reference [usually the point of waste discharge (t = 0)].

D = dissolved oxygen deficit (pounds per day) at any point, time t, from the point of reference.

L_o = ultimate biochemical oxygen demand loading (pounds per day) at the point of reference.

t = time of travel (days)

k_r = the coefficient of BOD removal in the watercourse by physical removal (sedimentation) and volatization (per day base e)

k_d = the coefficient of deoxygenation (per day, base e)

k = the coefficient of reoxygenation in the watercourse (per day, base e)

S = the rate of oxygen utilization by benthic deposits

$S = swv$, where:

s = oxygen uptake rate (pounds per square foot day)

w = average width of deposits (feet)

v = average velocity over deposit (feet per day)

Summaries of the data collected for modelling purposes are included below with a description of the parameter calculation used in applying the above equation to the Kaministikwia River.

A-3 FIELD INVESTIGATION

A survey designed to provide the water quality and physical information necessary for mathematical modelling was conducted during August 1970.

Activities included dye and drogue studies for time of travel and velocity, benthic respirometer studies to measure the oxygen demand of the bottom deposits and an intensive water quality study. The intensive study was conducted over a 72-hour period under relatively low flow conditions during the month of August when the water temperature was high. All major sources of pollution were discharging at the time of the survey.

The co-operation of Ontario Hydro was enlisted to maintain streamflow at a constant level of about 1,070 cfs. This flow exceeds the calculated low flow of 350 cfs (7-day average with a 5 percent chance of occurrence) but the higher flow was necessary to maintain aerobic conditions in the lower end of the study reach.

A-4 CALCULATION OF MODEL PARAMETERS

a) BOD Removal and Deoxygenation

The coefficients of BOD removal (k_r) and deoxygenation (k_d) are approximated directly from a plot of the BOD_5 data collected during the intensive studies. The reaction rate is the slope of the line resulting from the plotting of the log of the BOD values versus time of travel.

From the surface BOD_5 data collected during the 1970 study, it appears that a portion of the organic loading from The Great Lakes Paper Company Limited mill is lost in the first 0.3 day's travel below the mill. The loss of BOD is not accompanied by a significant loss of dissolved oxygen and based on this fact and the accumulations of sludge found in the area, it was assumed that the BOD was settling to the streambed. The slope derived from these points was assumed, therefore, to be a removal rate (k_r). Throughout the rest of the survey data, the loss of BOD was attributed primarily to the oxidation of organic materials and assumed to be deoxygenation rates (k_d).

The k_r and k_d rates thus established were employed in the modified Streeter-Phelps equation and, where necessary, were altered to more closely approximate the measured DO profiles.

b) Reoxygenation

Reoxygenation of a body of water occurs principally as a result of contact at the air-water interface. Oxygen diffuses from the atmosphere to the water at a rate determined by the amount of water coming in direct contact with the air. A turbulent stream obviously has a much greater ability for reaeration than does a slow or stagnant stream. The coefficient k_2 is determined using a constant diffusitivity coefficient (D_1), average stream depth (H) and average velocity (U) in the equation:

$$(D_1 . U)^{1/2} \times 24 = k_2/\text{day} \; ..... \; \text{(Manhattan 1968)}$$

In the case of the Kaministikwia River, the channel is dredged for shipping from the Westfort Turning Basin to Thunder Bay and has a fairly constant depth of 30 feet. The river water however does not flow to this depth. Temperature and velocity profiles indicate that the entire Lower Kaministikwia River is underlain by

by Thunder Bay water. In the upper reaches of the study area (Westfort Turning Basin to the Old Highway 61 Bridge), the river water occupies the top 20 feet but near the mouth, the river water occupies only the top 10 feet. Sampling indicated that very little mixing occurred between the surface river water and underlying bay water. Therefore, for the calculation of the k_2 rate only the depth of the warmer river water was employed. This depth averaged about 15 feet. It is generally recognized that the k_2 equation presented above is valid for streams up to 10-12 feet in depth. While the average depth of the Kaministikwia River exceeds this limit, it is believed that the values obtained are satisfactory first approximations of the reaeration rate.

c) Initial BOD and DO Loadings

Before a mathematical model can be produced a set of initial conditions must be established. In the case of the DO-BOD model, an initial oxygen deficit (D_o) and organic loading (L_o) are required.

The initial oxygen deficit (D_o) is determined from the survey findings. This value is the difference between the measured dissolved oxygen value and the 100 percent saturated DO value at survey water temperature. In the Kaministikwia River, initial conditions were measured at The Great Lakes Paper Company Limited mill waterworks intake, upstream from all major waste sources.

The initial BOD loading (L_o) is established using the BOD level measured in the watercourse directly downstream from the point of waste discharge. It is the sum of the upstream and wastewater discharge organic loading. L_o is expressed as ultimate BOD (see A.4.d).

For use in the DO-BOD model the measured values of D_o and L_o are converted to pounds per day by multiplying the concentration (mg/l) by the streamflow (cfs) and a conversion factor (5.4).

The formulation of a mathematical model requires a break in the calculations each time a significant waste source, tributary stream, physical change or K-rate change is encountered. At each break point, a new L_o and D_o must be established. These values are obtained from the final conditions computed in the previous section of the model plus any additional organic loading or oxygen deficit contributed by a waste source or tributary stream.

d) Ultimate Biochemical Oxygen Demand

The measure of deoxygenating organic matter is the 5-day biochemical oxygen demand value. This analysis measures the amount of oxygen consumed in an airtight bottle over a five day period. It is not a measure of the entire organic loading but simply a convenient measure to be compared with other BOD_5 values.

In the stream, the organic loading obviously does not end after five days, therefore, the ultimate BOD concentration is required. This value is determined using a constant "K_1" which is a laboratory measurement of the rate of BOD satisfaction over a long period of time, usually 20-25 days. With the K_1 value known, all BOD_5 concentrations can be converted to ultimate BOD using the function $(1-10^{-K_1 t})^{-1}$, where t equals five days (FWPCA 1966).

The K_1 rate measured and employed in the Kaministikwia River was 0.031 per day.

e) Benthic Oxygen Demand

Decaying sludge deposits can have a significant demand on the oxygen resources of a watercourse and this sink of oxygen is not measured in BOD samples. It, therefore, must be handled as a separate term in the equation. In some instances, the benthic oxygen demand can be measured directly by finding the dissolved oxygen drop in a known volume of water trapped directly over the deposit, computing the oxygen demand per unit area per unit time and estimating the total area of the sludge deposits.

The value "S" employed in the modified Streeter-Phelps equation represents the oxygen uptake rate (pounds per square foot - day) multiplied by the average width of the deposit (feet), the average velocity of the water over the deposits (feet/day), and the time interval (days).

In the Kaministikwia River, it was estimated that bottom deposits of wood, clay, fibre and wood chips covered the riverbed for a distance of about two miles downstream from the mill outfalls of The Great Lakes Paper Company Limited. The largest accumulations appeared to occur in the Westfort Turning Basin where regular dredging to facilitate shipping traffic is required.

Because of the relatively steep banks of the Kaministikwia River, very few sites suitable for the installation of the benthic

oxygen uptake measuring device could be found. In the area where the uptake rate was measured, the activity of the bottom deposits was found to be very low. An uptake rate of 0.33 grams of oxygen per square meter - day was measured. This is significantly less than the usually accepted range of 2-5 grams per square meter - day for pulp and paper type sludges (Stein 1966).

Another factor which had to be taken into account when considering the effects of the bottom deposits in the Kaministikwia River was the fact that the water which overlay the deposits was not flowing river water but trapped bay water (see discussion in text). The mathematical model considers only the surface flow and, therefore, the sludge term would not apply. No doubt the sludge demand does to some extent deplete the oxygen in the bottom water and this, in turn, will have some effect on the surface waters, but for the purpose of this model, the indirect effect of the sludge deposits was accounted for in the other reaction rates employed.

A-5 FITTING THE MODEL TO THE OBSERVED CURVE

Using the aforementioned rates (k_r, k_d and k_2) and the initial organic loading and dissolved oxygen levels, the oxygen deficit (D) is computed for selected time intervals along the reach under consideration. From these results an oxygen profile is plotted. This curve is then compared to the oxygen profile measured during the field investigation. The closeness of the fit indicates the accuracy of the model.

Because of the unique physical characteristics of the Kaministikwia River (two distinct water layers), it was found that the reaction rates established from physical and chemical characteristics had to be adjusted slightly to reproduce the dissolved oxygen profile. Both the k_r and k_d rates were adjusted upward about ten percent. The k_2 rates calculated were found to be much lower than required. These values were adjusted to fit the oxygen curve. Reaction rates and initial loading conditions are presented in Tables A-1 and A-2.

A-6 ALLOWABLE LOADING COMPUTATION

Employing the model, maximum expected water temperatures and low streamflows, organic waste loadings that would result in minimum dissolved oxygen levels of 5, 3 and 1 mg/l were estimated.

The organic loading calculated from the model under design conditions (elevated water temperature and drought streamflow) represents the maximum biochemical oxygen demand loading that the stream could accept and yet maintain a predetermined dissolved oxygen level. The estimation of this loading is subject to the limitations of the model and, as pointed out earlier, has been based upon only one attempt at mathematically modelling the Kaministikwia River.

APPENDIX B

APPENDIX B (PART 1)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY

ZONES 2* AND 3

Station	Dissolved Oxygen				Dissolved Oxygen % Saturation				BOD_5				Total Nitrogen as N				Total Phosphorus as P				Turbidity				Phenolic Substances			
	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
	mg/l								mg/l				mg/l				mg/l				mg/l				mg/l			
111	7.78	8.70	5.80	5	80.8	92.0	60.8	5	2.4	4.8	1.1	5	.348	.517	.274	5	.016	.035	.009	5	3.3	7.0	2.0	5	8.4	17.0	1.0	5
113	8.51	9.15	8.00	4	88.3	93.9	82.6	4	1.6	1.9	1.2	4	.282	.325	.246	4	.013	.013	.010	4	2.7	3.6	1.8	4	4.8	7.0	3.0	4
117	8.61	9.40	7.70	4	89.9	96.7	80.0	4	1.9	3.2	1.2	4	.352	.405	.313	4	.016	.026	.008	4	3.0	4.1	2.5	4	3.2	7.0	-	4
* 121	9.00	9.80	8.25	5	91.5	100.6	84.7	5	1.2	1.5	.7	5	.358	.415	.293	5	.015	.033	.003	5	4.7	6.5	1.8	5	1.0	1.0	1.0	5
* 124	8.11	9.20	7.25	5	83.5	95.2	71.2	5	1.2	1.6	.9	5	.499	.734	.304	5	.034	.076	.012	5	13.1	27.0	3.4	5	2.8	5.0	1.0	5
* 128	8.51	9.60	7.63	5	85.8	91.3	76.5	5	1.6	2.6	1.2	5	.408	.522	.326	5	.036	.072	.011	5	10.0	20.0	3.4	5	2.0	3.0	-	5
* 129	8.70	10.00	8.20	5	87.0	92.5	83.2	5	1.0	1.3	.4	5	.361	.415	.295	5	.023	.046	.014	5	4.3	7.2	1.5	5	2.0	5.0	-	5
* 131	8.59	9.60	8.25	5	87.3	89.6	86.3	5	1.1	1.6	.9	5	.335	.435	.275	5	.038	.120	.009	5	4.4	5.9	2.2	5	3.4	6.0	-	5
* 132	7.81	8.50	6.55	5	80.9	89.8	68.7	5	1.3	1.4	1.2	5	.346	.396	.295	4	.035	.094	.013	4	5.3	9.0	2.2	5	5.8	9.0	3.0	5
* 134	7.80	9.90	5.65	5	77.3	92.6	58.2	5	3.5	5.7	1.9	5	.359	.465	.274	5	.014	.020	.012	5	4.2	6.5	2.7	5	18 8	35.0	3.0	5
* 135	6.34	7.20	5.40	5	66.6	74.7	57.2	5	5.0	7.2	3.4	5	.416	.464	.335	5	.038	.110	.018	5	5.1	7.0	3.4	5	25.6	50.0	10.0	5
* 138	8.56	10.90	5.90	5	84.5	102.3	62.0	5	3.0	5.3	1.5	5	.375	.496	.275	5	.012	.020	.006	5	3.6	6.7	2.5	5	12.4	18.0	1.0	5
* 139	8.32	8.80	8.00	4	85.5	90.0	81.5	4	.8	1.2	.2	5	.327	.405	.254	4	.011	.018	.007	5	4.2	5.9	2.0	5	3.0	5.0	-	5
500	7.22	9.50	6.10	5	73.8	93.6	63.8	5	3.3	4.9	1.3	5	.350	.553	.195	4	.017	.037	.006	5	2.5	3.1	2.0	5	17.4	40.0	2.0	5
501	8.29	9.85	7.10	5	85.5	100.0	73.8	5	1.9	3.1	1.1	5	.330	.424	.214	5	.012	.020	.006	5	2.4	3.1	1.6	5	6.8	12.0	1.0	5
502	8.75	10.00	5.50	5	87.1	96.8	57.2	5	2.0	5.0	.8	5	.364	.516	.234	5	.012	.026	.007	5	2.6	3.4	2.2	5	5.2	17.0	2.0	5
503	8.99	10.05	7.60	5	89.8	99.0	79.3	5	1.6	2.1	1.1	5	.297	.404	.255	4	.016	.030	.007	5	2.3	3.6	1.8	5	2.8	7.0	-	5
504	9.42	10.30	8.40	5	95.9	100.4	87.0	5	1.1	1.6	.8	5	.289	.355	.185	5	.006	.009	.003	4	2.1	3.4	1.4	5	1.8	3.0	1.0	5
505	9.62	10.10	9.20	5	100.0	105.0	96.4	5	.9	1.4	.7	5	.274	.334	.194	5	.007	.010	.004	5	2.0	2.2	1.8	5	2.0	3.0	1.0	5
506	8.60	10.40	6.20	5	87.7	99.8	64.6	5	2.0	4.5	1.0	5	.329	.525	.214	5	.019	.052	.005	5	2.7	3.9	1.6	5	5.6	17.0	1.0	5
507	8.15	9.75	6.10	5	83.7	97.2	63.3	5	2.3	4.6	1.0	5	.334	.464	.233	5	.013	.026	.006	5	2.6	3.9	1.8	5	6.8	12.0	3.0	5
508	8.30	9.10	7.40	5	86.6	96.4	77.7	5	2.3	3.7	1.0	5	.339	.445	.254	4	.013	.018	.005	4	2.5	3.6	1.8	4	8.0	12.0	5.0	5
509	8.49	9.50	7.10	5	87.8	96.4	74.6	5	1.7	2.6	1.2	5	.343	.424	.235	5	.011	.014	.006	5	2.6	3.4	1.8	5	5.8	12.0	1.0	5
510	9.04	10.00	8.00	5	92.7	101.7	83.5	5	1.4	1.8	1.1	5	.287	.363	.194	5	.013	.027	.005	5	2.3	3.1	1.4	5	4.0	5.0	3.0	5
511	9.73	10.80	9.30	5	97.4	99.7	94.5	5	.8	1.2	.1	5	.315	.414	.205	5	.007	.013	.005	5	2.8	3.9	1.6	5	2.0	3.0	1.0	5
512	10.16	11.40	9.20	9	97.8	102.3	89.7	9	.9	1.2	.5	9	.29	.363	.225	9	.008	.018	.003	9	2.6	5.6	1.6	9	2.1	5.0	-	9
513	10.30	11.30	9.20	10	99.1	101.7	95.6	10	1.0	1.4	.5	10	.282	.462	.183	10	.006	.008	.003	10	2.0	3.1	1.4	10	.9	1.0	-	10
514	8.96	10.00	6.90	5	88.1	99.9	71.7	5	1.5	2.3	1.1	4	.283	.334	.194	5	.009	.020	.005	5	2.2	2.9	1.4	5	6.8	12.0	3.0	5
515	8.88	9.80	8.30	4	90.8	97.5	84.3	4	1.2	1.6	.9	4	.315	.376	.275	4	.014	.024	.005	4	2.5	3.1	1.8	4	2.8	5.0	1.0	4
516	9.55	10.20	9.00	4	94.3	99.9	89.9	4	1.1	1.4	.6	3	.354	.475	.263	4	.008	.012	.005	4	2.5	3.4	1.6	4	1.0	1.0	1.0	3

(appendix B, part 1, cont'd)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY

ZONES 2* AND 3

Station	Dissolved Oxygen (mg/l)				Dissolved Oxygen % Saturation (mg/l)				BOD_5 (mg/l)				Total Nitrogen as N (mg/l)				Total Phosphorus as P (mg/l)				Turbidity (mg/l)				Phenolic Substances (mg/l)			
	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
517	9.98	10.70	9.20	6	93.6	98.8	81.9	6	1.1	1.4	.8	6	.329	.393	.194	6	.006	.008	.002	6	2.1	3.1	1.6	6	1.3	2.0	1.0	6
* 518	6.73	8.30	5.80	5	68.6	77.5	60.8	5	4.3	7.2	1.4	5	.391	.608	.274	4	.033	.104	.013	5	8.1	18.0	4.6	5	26.2	50.0	1.0	5
* 519	7.71	9.00	7.20	5	79.7	90.8	72.5	5	2.0	2.3	1.6	5	.378	.434	.335	4	.020	.026	.016	5	2.0	2.3	1.6	5	7.6	13.0	3.0	5
* 520	8.29	8.90	7.75	5	84.2	90.7	81.4	5	1.3	1.6	.9	5	.438	.485	.415	3	.044	.060	.028	4	11.2	19.0	4.6	5	2.0	7.0	-	5
* 521	8.06	9.60	7.40	5	81.3	92.6	72.0	5	1.3	1.9	.9	5	.543	.727	.355	5	.053	.078	.024	5	13.5	19.0	5.6	5	3.0	5.0	1.0	5
522	9.60	9.90	9.10	5	96.8	99.1	94.5	5	1.0	1.5	.4	5	.304	.439	.195	4	.009	.014	.004	5	2.9	3.9	1.6	5	2.4	7.0	-	5
523	10.70	10.40	11.10	5	99.5	102.5	96.4	5	.6	1.0	.3	5	.285	.415	.190	4	.007	.014	.002	5	2.7	3.9	1.6	5	.6	1.0	-	5
524	10.30	11.30	9.00	11	98.0	101.8	90.9	11	.7	1.3	.3	11	.318	.484	.163	9	.006	.014	.002	11	2.5	3.4	1.8	11	1.5	5.0	-	11
525	10.46	11.30	9.70	6	98.8	105.7	94.6	6	1.2	1.6	.9	6	.316	.384	.214	6	.006	.009	.003	6	2.1	2.9	1.4	6	1.3	3.0	-	6
526	9.55	9.95	9.10	5	95.8	100.2	87.3	5	1.0	1.2	.9	5	.324	.424	.184	5	.006	.010	.003	4	2.4	3.4	1.8	5	1.4	5.0	-	5
527	8.95	9.25	8.50	5	92.5	95.0	87.8	5	1.3	1.7	.8	5	.324	.404	.204	5	.009	.011	.007	5	2.6	2.9	2.0	5	2.4	5.0	1.0	5
528	8.20	8.95	6.60	5	84.8	93.3	68.2	5	1.7	2.6	1.0	5	.333	.415	.294	5	.014	.022	.007	5	2.5	2.9	2.0	5	3.8	7.0	1.0	5
529	9.94	11.20	8.00	7	96.8	104.6	82.6	7	1.0	1.3	.7	7	.290	.355	.203	7	.009	.022	.003	7	2.5	4.8	1.4	7	1.6	5.0	-	5
530	9.25	9.45	9.00	5	96.1	98.0	94.3	5	1.5	1.9	1.1	5	.266	.314	.224	5	.006	.008	.003	5	2.4	2.7	2.2	5	1.6	5.0	-	5
531	9.91	10.40	9.30	5	98.1	98.6	96.8	5	1.1	1.5	.7	5	.326	.395	.293	5	.011	.028	.004	5	2.4	2.9	2.0	5	1.6	3.0	1.0	5
532	10.08	11.10	7.80	7	93.9	100.2	80.1	7	1.2	1.6	.7	7	.324	.405	.227	7	.008	.010	.003	6	2.1	2.9	1.4	7	1.7	4.0	-	5
533	10.27	11.11	9.10	9	97.5	100.5	95.0	9	1.0	1.7	.6	9	.293	.414	.204	9	.007	.012	.004	9	2.3	2.7	2.0	9	1.6	5.0	-	9
534	9.78	10.20	9.30	5	96.7	99.6	93.8	5	1.1	1.8	.6	5	.324	.354	.294	5	.011	.028	.005	5	2.1	2.5	2.0	5	1.2	3.0	-	5
535	9.33	9.80	8.85	5	94.2	98.6	91.8	5	1.1	1.9	.6	5	.292	.344	.253	5	.008	.010	.005	5	2.0	2.2	1.8	5	1.4	3.0	-	5
* 536	8.55	9.00	8.10	5	86.3	91.6	83.9	5	1.4	2.1	1.0	5	.423	.363	.285	5	.017	.024	.004	5	3.0	4.3	2.0	5	2.6	5.0	1.0	5
537	9.07	10.90	7.50	4	91.3	99.3	78.8	4	5.0	9.0	1.2	4	.357	.415	.324	3	.007	.010	.003	4	3.2	5.1	2.0	4	1.5	5.0	-	4
538	9.58	11.20	8.50	4	96.5	101.1	89.7	4	1.5	2.6	.7	4	.344	.355	.335	3	.006	.009	.003	4	2.5	3.1	1.8	4	3.0	9.0	-	4
539	9.20	10.60	7.80	4	92.8	97.3	81.8	4	2.5	5.0	1.2	4	.310	.354	.283	3	.007	.013	.002	4	2.3	3.4	1.4	4	3.8	7.0	-	4
540	9.18	11.10	8.20	4	94.5	99.9	85.6	4	2.6	6.3	1.2	4	.314	.364	.284	3	.007	.013	.003	4	2.5	4.1	1.8	4	1.0	3.0	-	4
541	9.90	11.00	9.40	4	99.4	101.4	98.1	4	2.1	4.7	1.2	4	.330	.414	.283	3	.005	.008	.003	3	2.4	3.6	1.6	4	7.2	25.0	-	4
542	9.49	11.00	9.10	4	95.6	96.8	91.1	4	1.3	1.5	1.1	4	.355	.507	.264	3	.005	.007	.002	4	2.4	3.1	1.4	4	2.2	5.0	-	4
543	10.44	11.50	9.05	4	101.1	107.4	94.9	4	.9	1.6	.6	4	.359	.394	.323	3	.006	.009	.005	3	2.6	3.0	1.8	3	2.0	7.0	-	4
544	10.81	11.50	9.95	4	100.8	102.4	98.2	4	1.1	1.4	.9	4	.309	.419	.244	3	.007	.013	.003	4	2.2	3.0	1.4	4	1.0	2.0	-	4
545	10.60	11.50	9.10	6	100.7	114.3	91.6	6	1.3	3.0	.6	6	.300	.455	.273	4	.004	.007	.002	6	1.9	2.9	1.1	6	1.7	9.0	-	6
546	10.42	11.50	9.30	8	100.7	104.9	97.7	8	.8	1.3	.4	8	.270	.375	.184	7	.004	.007	.002	8	2.0	3.6	1.4	8	1.2	3.0	-	8
547	10.60	11.50	9.70	4	98.6	100.8	96.9	4	1.4	1.6	1.2	4	.354	.404	.285	3	.019	.064	.002	4	2.3	3.4	1.5	4	2.5	7.0	-	4

(appendix B, part 1, cont'd)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY

ZONES 2* AND 3

Station	Dissolved Oxygen				Dissolved Oxygen % Saturation				BOD_5				Total Nitrogen as N				Total Phosphorus as P				Turbidity				Phenolic Substances			
	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
	mg/l				mg/l				mg/l				mg/l				mg/l				mg/l				mg/l			
548	10.43	11.50	9.80	4	100.2	103.5	98.1	4	1.3	1.9	.9	4	.352	.388	.324	3	.006	.008	.002	4	2.0	3.1	1.5	4	1.2	3	-	4
549	9.94	11.50	8.65	4	95.6	100.7	85.9	4	1.3	1.9	.7	4	.351	.385	.304	3	.008	.020	.002	4	2.0	3.1	1.5	4	2.8	9	-	4
550	10.06	11.70	9.10	4	97.2	100.7	93.4	4	1.2	1.5	.7	4	.359	.363	.355	2	.010	.031	.002	4	2.0	2.9	1.4	4	1.5	3	-	4
551	11.32	11.70	10.90	4	102.9	106.6	98.8	4	1.1	1.6	.6	4	.279	.393	.205	4	.009	.018	.005	4	2.4	2.7	2.0	4	0.2	1	-	4
552	10.23	11.30	9.30	8	97.9	100.8	95.0	8	.9	1.0	.5	8	.314	.385	.274	6	.018	.060	.003	8	2.5	3.4	1.8	8	1.6	3	-	8
553	10.40	11.15	9.75	4	99.3	103.0	96.2	4	.8	1.4	.2	4	.321	.454	.245	3	.005	.008	.003	4	2.7	3.1	2.2	4	1.8	4	-	4
554	10.25	11.30	9.10	8	99.3	101.6	96.4	8	.7	1.6	.2	8	.295	.415	.133	6	.006	.009	.003	8	2.6	3.4	1.6	8	2.0	5	-	8
555	10.38	11.35	9.20	6	98.3	100.2	96.7	6	1.1	1.9	.4	6	.284	.404	.141	6	.006	.010	.002	6	2.8	3.9	1.6	6	1.5	3	-	6
7-001	5.45	5.45	5.45	1	56	56	56	1	124.7	160.0	84.0	3	13.633	21.456	1.400	3	5.110	10	.840	3	29.0	35.0	23.0	3	8.0	12	3	3
7-002	7.61	7.90	7.30	5	80	83	75	5	163.8	727.0	4.8	5	1.628	3.163	.474	5	.351	.700	.027	4	4.3	7.0	2.2	5	27.4	50	5	5
9-008	-	-	-	-	-	-	-	-	667	1600	44.0	4	2.919	5.028	1.507	3	.561	.115	.132	3	50.0	62.0	44.0	3	-	-	-	4
9-011	4.80	7.60	0.35	5	49	73	3	5	3.5	6.8	2.0	5	.686	.904	.543	5	.102	.132	.080	5	7.9	18.0	3.1	5	5.2	10	2	5
15-001	1.74	5.20	-	6	18	55	-	6	14.0	36.0	3.9	6	.408	.584	.075	5	.050	.078	.019	6	4.2	8.5	1.8	6	17.0	25	9	6
15-002	5.31	8.30	1.10	5	54	87	11	5	3.7	8.2	1.3	5	.487	.575	.230	5	.068	.190	.011	5	2.7	3.4	2.2	5	8.2	15	2	5
15-003	7.28	9.50	4.30	5	72	93	45	5	2.1	3.0	1.0	5	.484	.685	.285	5	.058	.120	.014	5	2.9	3.1	2.7	5	5.0	7	3	5
15-004	2.40	2.40	2.40	1	26	26	26	1	41.1	60.0	2.2	4	10.322	16.007	5.705	3	1.630	3.4	.320	4	63.0	140	13.0	4	20.5	35	5	4
15-006	7.15	7.15	7.15	1	81	81	81	1	4.2	4.5	3.8	3	2.300	4.036	1.360	3	.076	.100	.038	4	4.8	7.0	2.2	4	3.0	5	2	3
15-007	8.70	8.70	8.70	1	93	93	93	1	5.4	14.0	1.8	4	2.505	4.774	1.120	3	.389	1.2	.022	4	29.2	65.0	4.8	4	2.2	5	-	4
15-008	8.15	8.15	8.15	1	91	91	91	1	2.2	2.8	1.9	4	1.462	3.050	.653	3	.128	.400	.011	4	4.4	6.5	3.1	4	4.8	12	1	4

APPENDIX B (PART 11)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY

ZONES 2* AND 3

Station	Fecal Streptococci				Fecal Coliforms				Total Coliforms				Total Solids				Suspended Solids				Dissolved Solids			
	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
	per 100 ml												mg/l				mg/l				mg/l			
111	41	152	10	5	276	436	112	5	2398	3300	870	5	83.6	138	38	5	5.4	9	2	5	78.2	130	35	5
113	55	180	16	4	127	284	48	4	2395	3800	780	4	67.0	112	32	4	3.75	6	-	4	62.0	106	32	4
117	28	350	-	5	161	780	20	5	3412	6700	2100	5	83.5	108	64	4	3.5	5	1	4	80.0	103	63	4
* 121	63	224	4	4	91	404	20	5	1379	7900	260	5	58.6	96	46	5	11.4	40	-	5	47.2	56	40	5
* 124	917	6400	150	4	132	404	36	5	3849	17000	180	5	87.6	132	50	5	18.4	50	10	5	71.2	121	40	5
* 128	1443	2200	580	4	173	232	100	5	3281	4600	1400	4	77.6	100	60	5	13.4	22	10	5	64.2	89	38	5
* 129	250	620	126	4	130	172	108	5	2187	4300	1100	4	80.4	106	54	5	14.2	37	5	5	66.2	97	41	5
* 131	150	576	60	5	185	480	100	5	2068	3300	750	5	75.2	90	64	5	5.6	8	3	5	69.6	86	56	5
* 132	87	128	56	5	395	1020	140	5	3307	8600	1500	5	74.0	104	48	5	8.4	19	5	5	65.6	96	45	5
* 134	149	492	64	5	695	1720	430	5	4524	13000	810	5	80.4	94	56	5	8.4	12	3	5	72.0	84	46	5
* 135	86	176	44	5	566	680	468	5	3204	7700	470	4	90.8	120	74	5	8.4	15	2	5	82.4	105	69	5
* 138	51	144	8	5	358	860	160	5	2777	8000	630	5	76.4	100	52	5	6.2	11	2	5	70.2	89	43	5
* 139	75	740	4	5	183	316	100	5	2058	3800	660	5	72.4	106	52	5	5.4	10	1	5	67.0	102	47	5
500	90	156	36	5	360	520	252	5	2569	4100	620	5	86.4	126	54	5	4.2	6	2	5	82.2	120	49	5
501	48	90	16	5	162	260	88	5	1920	2900	600	5	73.2	110	44	5	3.2	6	-	5	70.0	104	41	5
502	33	192	12	5	118	304	24	5	1645	4100	630	5	74.0	114	42	5	3.8	6	1	5	70.2	110	39	5
503	19	124	-	5	64	220	8	5	1545	4200	460	5	63.6	90	28	5	3.4	5	2	5	60.2	86	26	5
504	2	6	-	5	6	152	-	5	854	5000	150	5	67.2	80	56	5	2.0	4	1	5	65.2	79	52	5
505	2	22	-	5	38	160	4	5	1276	4100	290	5	70.8	100	36	5	1.9	3	-	5	69.0	97	36	5
506	16	102	4	5	119	284	20	5	1529	2700	500	5	80.8	116	50	5	3.6	6	1	5	77.2	110	47	5
507	41	148	8	5	179	400	92	5	2112	4100	1300	5	79.2	112	56	5	44.0	6	1	5	74.8	106	52	5
508	41	236	8	5	298	600	120	5	1892	5700	400	5	84.5	104	62	4	4.5	8	2	4	80.0	99	59	4
509	26	142	4	5	193	400	72	5	2518	2900	2100	5	73.6	110	44	5	4.0	6	2	5	69.6	104	39	5
510	21	52	4	4	71	232	4	4	1117	2700	610	4	69.2	96	48	5	3.8	7	2	5	65.4	91	46	5
511	2	4	-	5	10	372	-	5	777	4300	40	5	72.8	104	58	5	3.6	7	1	5	69.2	99	57	5
512	2	66	-	7	26	300	-	7	280	1200	60	7	65.2	78	38	9	2.6	6	1	8	62.6	75	37	8
513	1	6	-	11	3	140	-	11	200	2700	30	11	68.8	94	34	10	1.7	4	-	10	67.1	91	33	10
514	17	110	4	5	156	296	52	5	1474	3800	380	5	72.4	108	54	5	3.0	5	2	5	69.4	105	52	5
515	43	180	6	3	80	328	12	3	2378	3200	2000	3	73.0	122	40	4	9.0	20	3	4	62.0	115	34	4
516	8	80	-	4	62	108	12	4	883	2600	200	4	71.0	112	48	4	4.3	7	2	4	66.7	105	45	4

(appendix B, part 11, cont'd)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY

ZONES 2* AND 3

Station	Fecal Streptococci				Fecal Coliforms				Total Coliforms				Total Solids				Suspended Solids				Dissolved Solids			
	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
	per 100 ml												mg/l				mg/l				mg/l			
517	2	28	-	8	7	80	-	8	230	1400	10	8	67.8	84	50	6	2.6	4	2	6	65.2	82	48	6
* 518	79	160	36	5	418	780	264	5	3464	4300	3000	4	104.8	198	64	5	21.0	80	3	5	83.7	118	58	5
* 519	132	212	88	5	621	3140	56	5	5011	7700	2800	5	79.6	112	52	5	9.6	15	5	5	70.0	97	37	5
* 520	1735	10000	180	3	149	320	64	5	1939	4300	1060	3	80.8	114	58	5	11.0	20	3	5	71.8	104	43	5
* 521	483	800	292	2	429	960	160	5	9997	30000	5800	5	92.8	144	52	5	20.6	40	12	5	72.2	132	38	5
522	3	34	-	6	63	292	8	7	1085	7700	190	7	66.0	106	42	5	7.4	24	2	5	58.6	82	40	5
523	2	12	-	4	25	84	4	4	405	3200	40	4	76.5	98	58	4	3.6	11	-	4	72.9	87	55	4
524	1	20	-	17	20	164	-	17	406	10100	20	18	65.6	92	40	11	2.4	9	-	11	63.2	88	38	11
525	2	18	-	4	35	200	12	4	1096	5200	300	4	69.6	78	54	6	2.0	5	1	6	67.6	77	53	6
526	2	30	-	5	13	52	4	5	112	13000	170	5	72.4	112	56	5	4.4	8	1	5	68.0	107	48	5
527	14	196	-	5	74	336	16	5	1777	3000	830	5	72.0	106	40	5	4.2	8	1	5	68.8	98	38	5
528	93	448	12	4	147	216	112	4	2121	3800	960	4	81.2	108	56	5	3.8	7	-	5	77.4	101	52	5
529	2	20	-	7	20	64	8	7	306	3000	20	7	67.5	80	48	7	3.1	7	2	7	64.4	77	46	7
530	4	48	-	5	10	116	-	5	1556	4000	330	5	74.8	114	52	5	1.8	3	1	5	73.0	114	51	5
531	3	14	-	5	10	28	-	5	1305	4300	290	5	70.4	110	50	5	2.0	5	-	5	68.4	105	50	5
532	2	8	-	6	6	24	-	6	393	1800	120	6	62.2	96	40	7	2.6	6	-	7	59.6	92	40	7
533	1	4	-	9	5	124	-	9	455	3000	170	9	57.6	74	42	9	3.9	10	1	9	53.7	70	32	9
534	2	6	-	5	18	76	-	5	1080	3900	370	5	71.2	100	46	5	2.6	7	-	5	68.6	98	46	5
535	4	14	-	5	49	132	12	5	1551	4300	520	5	56.8	72	32	5	1.8	3	1	5	55.0	70	31	5
* 536	226	512	128	4	244	620	60	5	3851	9100	2000	5	71.6	102	38	5	5.2	10	3	5	66.4	97	33	5
537	50	184	16	4	1162	2260	500	3	9035	11200	7400	3	89.5	114	52	4	5.5	7	4	4	84.0	110	46	4
538	14	58	-	4	141	288	36	3	2875	6300	650	3	62.0	80	42	4	3.5	5	3	4	58.5	77	39	4
539	16	48	-	4	50	356	-	3	3730	13600	530	3	83.5	110	56	4	4.5	6	2	4	79.0	105	50	4
540	10	36	-	4	94	260	24	3	2805	5900	680	3	84.0	104	64	4	4.8	5	4	4	79.2	99	59	4
541	10	70	-	4	28	286	-	3	2891	10200	640	3	70.0	90	46	4	3.8	5	2	4	66.2	86	42	4
542	7	30	-	4	6	32	-	2	3078	14400	450	3	69.3	94	50	4	3.5	5	2	4	65.8	89	48	4
543	4	57	-	4	21	116	-	3	1914	3900	620	3	61.3	90	32	3	2.3	5	-	3	59.0	85	32	3
544	2	4	-	4	25	268	4	4	931	3300	150	4	67.0	102	42	4	3.0	5	1	4	64.0	98	41	4
545	3	44	-	6	59	684	-	6	954	16500	170	6	66.0	90	54	6	3.3	5	2	6	62.7	87	46	6
546	1	4	-	8	4	132	-	8	520	10400	40	8	76.8	96	44	8	7.5	20	2	8	69.3	93	42	8
547	2	34	-	4	19	364	-	3	1414	4100	300	3	65.3	98	40	4	3.5	5	2	4	61.8	96	38	4

(appendix B, part 11, cont'd)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY
ZONES 2* AND 3

Station	Fecal Streptococci				Fecal Coliforms				Total Coliforms				Total Solids				Suspended Solids				Dissolved Solids			
	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
	per 100 ml												mg/l				mg/l				mg/l			
548	2	16	-	4	5	12	-	3	653	1600	290	3	76	108	50	4	3.5	5	2	4	72.5	103	47	4
549	3	44	-	4	7	24	4	3	667	1240	470	4	86	110	46	4	2.8	5	1	4	83.2	105	43	4
550	7	62	-	4	60	356	8	3	2275	5300	1010	3	79	102	66	4	3.8	5	2	4	75.2	97	64	4
551	2	4	-	4	9	184	-	4	212	1900	30	4	80	94	66	3	3.5	8	1	4	76.5	91	65	3
552	1	2	-	8	6	100	-	8	642	5300	70	8	65.7	90	34	8	3.6	8	-	8	62.1	88	30	8
553	13	36	8	3	97	244	56	4	859	3400	200	4	76.8	92	42	4	4.0	6	-	4	72.8	87	36	4
554	1	4	-	8	15	304	-	8	464	8100	70	8	62.7	94	36	8	5.4	15	-	8	57.3	91	33	8
555	1	2	-	6	6	124	-	6	522	5800	70	6	53.6	72	34	6	3.6	7	-	6	50.0	69	31	6
7-001	2.4×10^5	3.0×10^5	1.99×10^5	2	7.8×10^4	8.0×10^4	7.5×10^4	2	17.4×10^4	18.9×10^4	16×10^4	2	297.3	334	278	3	43.3	70	5	3	254	273	225	3
7-002	6.9×10^4	1.1×10^5	5.3×10^4	3	9.0×10^5	1.7×10^6	3.5×10^5	4	3.3×10^4	15.3×10^4	1.7×10^3	5	94.8	144	70	5	10.8	18	7	5	84	132	62	5
9-008																	105.0	160	50	2	1921.7	3790	1970	2
9-011	1.4×10^4	4.0×10^4	4900	2	1025	4200	120	5	9.1×10^5	6.7×10^6	8.7×10^4	5	81.2	106	58	5	14.2	30	5	5	67	101	48	5
15-001	1974	7500	520	2	2264	4300	1000	3	4.4×10^5	4.8×10^5	8000	4	141.7	214	98	6	12.0	17	-	6	129.7	202	94	6
15-002													99.1	118	60	5	3.8	6	2	5	95.3	113	58	5
15-003	1824	3400	940	4	1267	4700	80	5	1.5×10^4	3.1×10^4	3000	5	78.9	112	58	5	5.8	10	3	5	73.1	108	55	5
15-004	1.4×10^4	1.2×10^5	2000	4	1.4×10^5	7.6×10^5	2.0×10^4	4	1.9×10^6	7.6×10^6	4.8×10^5	3	394.3	549	220	4	98.2	360	6	4	296.1	472	189	4
15-006	484	1280	270	4	1045	2660	660	4	3010	1.5×10^4	1200	4	281.5	308	264	4	8.3	12	5	4	273.2	361	252	4
15-007	2971	6400	1200	4	1409	3500	800	3	4.0×10^4	1.4×10^5	1.9×10^4	4	380.5	600	200	4	133.8	290	7	4	246.7	387	152	4
15-008	269	310	210	3	70	80	10	3	394	500	310	2	81.3	100	66	3	9.7	20	4	3	71.6	80	62	3

(appendix B, part 11, cont'd)

SUMMARY OF WATER QUALITY DATA, AUGUST 1970 - THUNDER BAY
ZONES 2* AND 3

Station	Fecal Streptococci				Fecal Coliforms				Total Coliforms				Total Solids				Suspended Solids				Dissolved Solids			
	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Geom. Means	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.	Avg.	Max.	Min.	No.
	per 100 ml												mg/1				mg/1				mg/1			
548	2	16	-	4	5	12	-	3	653	1600	290	3	76	108	50	4	3.5	5	2	4	72.5	103	47	4
549	3	44	-	4	7	24	4	3	667	1240	470	4	86	110	46	4	2.8	5	1	4	83.2	105	43	4
550	7	62	-	4	60	356	8	3	2275	5300	1010	3	79	102	66	4	3.8	5	2	4	75.2	97	64	4
551	2	4	-	4	9	184	-	4	212	1900	30	4	80	94	66	3	3.5	8	1	4	76.5	91	65	3
552	1	2	-	8	6	100	-	8	642	5300	70	8	65.7	90	34	8	3.6	8	-	8	62.1	88	30	8
553	13	36	8	3	97	244	56	4	859	3400	200	4	76.8	92	42	4	4.0	6	-	4	72.8	87	36	4
554	1	4	-	8	15	304	-	8	464	8100	70	8	62.7	94	36	8	5.4	15	-	8	57.3	91	33	8
555	1	2	-	6	6	124	-	6	522	5800	70	6	53.6	72	34	6	3.6	7	-	6	50.0	69	31	6
7-001	2.4×10^5	3.0×10^5	1.99×10^5	2	7.8×10^6	8.0×10^6	7.5×10^6	2	17.4×10^6	18.9×10^6	16×10^6	2	297.3	334	278	3	43.3	70	5	3	254	273	225	3
7-002	6.9×10^4	1.1×10^5	5.3×10^4	3	9.0×10^5	1.7×10^6	3.5×10^5	4	3.3×10^6	15.3×10^6	1.7×10^5	5	94.8	144	70	5	10.8	18	7	5	84	132	62	5
9-008																	105.0	160	50	2	1921.7	3790	1970	2
9-011	1.4×10^4	4.0×10^4	4900	2	1025	4200	120	5	9.1×10^5	6.7×10^6	8.7×10^4	5	81.2	106	58	5	14.2	30	5	5	67	101	48	5
15-001	1974	7500	520	2	2264	4300	1000	3	4.4×10^5	4.8×10^5	8000	4	141.7	214	98	6	12.0	17	-	6	129.7	202	94	6
15-002													99.1	118	60	5	3.8	6	2	5	95.3	113	58	5
15-003	1824	3400	940	4	1267	4700	80	5	1.5×10^4	3.1×10^4	3000	5	78.9	112	58	5	5.8	10	3	5	73.1	108	55	5
15-004	1.4×10^4	1.2×10^5	2000	4	1.4×10^5	7.6×10^5	2.0×10^4	4	1.9×10^6	7.6×10^6	4.8×10^5	3	394.3	549	220	4	98.2	360	6	4	296.1	472	189	4
15-006	484	1280	270	4	1045	2660	660	4	3010	1.5×10^4	1200	4	281.5	308	264	4	8.3	12	5	4	273.2	301	252	4
15-007	2971	6400	1200	4	1409	3500	800	3	4.0×10^4	1.4×10^5	1.9×10^4	4	380.5	600	200	4	133.8	290	7	4	246.7	387	152	4
15-008	269	310	210	3	20	80	10	3	394	500	310	2	81.3	100	66	3	9.7	20	4	3	71.6	80	62	3

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